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Progress in Cultural Heritage: Documentation, Preservation, and Protection

5th International Conference, EuroMed 2014
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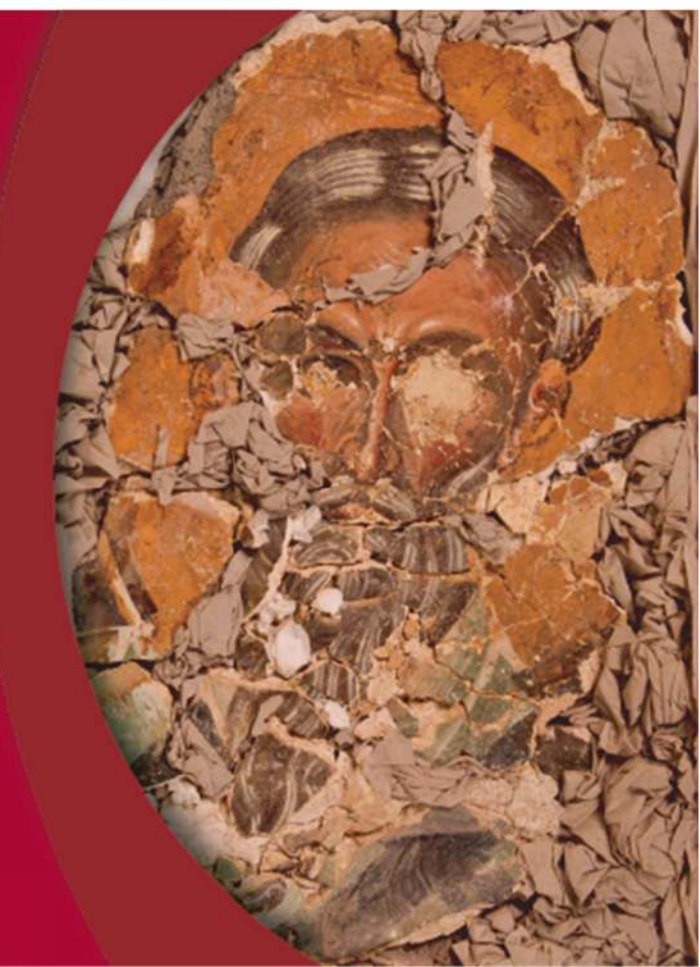

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Preface

Welcome to the proceedings of the 5th EuroMed Conference, the traditional biennial scientific event, which was held in the ancient city of Amathus, located in Limassol, Cyprus. The island has always been a bridge to three continents in the world going back to the origins of civilization. It is a place where the fingerprints of several ancient cultures and civilizations on earth can be found, with a wealth of historical sites recognized and protected by UNESCO.

Several organizations and current EU projects (such as the Marie-Curie Fellowship project on Digital Heritage ITN-DCH, the IAPP 4D-CH-WORLD, the LoCloud, the EuropeanaSpace, the DARIAH-EU ERIC and DARIAH-CY projects) decided to join EuroMed2014 and continue their cooperation together in order to create an optimal environment for the discussion and explanation of new technologies, exchange of modern innovative ideas, and in general to allow the transfer of knowledge between a large number of professionals and academics during one common event and time period.

The main goal of the event is to illustrate the programs underway, whether organized by public bodies (e.g., UNESCO, European Union, National States, etc.) or by private foundations (e.g., Getty Foundation, World Heritage Foundation, etc.) in order to promote a common approach to the tasks of recording, documenting, protecting, and managing World Cultural Heritage. The 5th EuroMed Conference was definitely a forum for sharing views and experiences and discussing proposals for the optimum attitude as well as the best practice and the ideal technical tools to preserve, document, manage, present/visualizes, and disseminate the rich and diverse cultural heritage of mankind.

This conference was held during the first year of the new Framework Programme, Horizon 2020, which is the largest in the world in terms of financial support for research, innovation, technological development, and demonstration activities. The awareness of the value and importance of heritage assets has been reflected in the financing of projects since the first Framework Programme for Research & Technological Development (FP1, 1984-87) and continues into the current HORIZON 2020 that follows FP7 (2007-13). In the past 30 years, a large community of researchers, experts, and specialists have had a chance to learn and develop the transferable knowledge and skills needed to inform stakeholders, scholars, and students. Europe has become a leader in heritage documentation, preservation, and protection science, with COST Actions adding value to projects financed within the FP and EUREKA program and transferring knowledge to practice and supporting the development of SMEs.

The EuroMed2014 agenda focused on the enhancement and strengthening of international and regional cooperation and promoting awareness and tools for future innovative research, development, and applications to protect, preserve, and document the European and World Cultural Heritage. Our ambition was to host an exceptional conference by also mobilizing policy makers from different EU countries, institutions (European Commission, European Parliament, Council of Europe, UNESCO, International Committee for Monuments and Sites ICOMOS, the International Committee for Documentation of Cultural Heritage CIPA, the International Society for Photogrammetry and Remote Sensing ISPRS, the International Centre for the study of the Preservation and Restoration of Cultural Property ICCROM, and the International Committee for Museums ICOM), professionals, as well as participants from all over the world and from different scientific areas of cultural heritage.

Protecting, preserving, and presenting our cultural heritage are actions that are frequently interpreted as change management and/or change of the behavior of society. Joint European and international research projects provide the scientific background and support for such a change. We are living in a period characterized by rapid and remarkable changes in the environment, in society, and in technology. Natural changes, war conflicts, and man-made changes, including climate, as well as technological and societal changes, form an ever-moving and colorful stage and pose a challenge for society. Close cooperation between professionals, policy makers, and authorities internationally is necessary for research, development, and technology in the field of cultural heritage.

Scientific projects in the area of cultural heritage have received national, European Union, or UNESCO funding for more than 30 years. Through financial support and cooperation, major results have been achieved and published in peer-reviewed journals and conference proceedings with the support of professionals from many countries. The European Conferences on Cultural Heritage research and development and in particular the biennial EuroMed conference have become regular milestones in the never-ending journey in search for new knowledge of our common history and its protection and preservation for the generations to come. EuroMed also provides a unique opportunity to present and review results as well as to draw new inspiration.

To reach this ambitious goal, the topics covered include experiences in the use of innovative technologies and methods and how to take best advantage to integrate the results obtained to build up new tools and/or experiences as well as to improve methodologies for documenting, managing, preserving, and communicating cultural heritage.

Here, we present 84 papers, selected from 438 submissions that focus on interdisciplinary and multidisciplinary research concerning cutting-edge cultural heritage informatics, physics, chemistry, and engineering and the use of technology for the representation, documentation, archiving, protection, preservation, and communication of cultural heritage knowledge.

Our keynote speakers, Mr. Gustavo Araoz (ICOMOS President), Mr. Roberto Scopignio (Director at ISTI, CNR), Mr. Timothy Whalen (Getty Director), Mr. France Desmarais (ICOM), Mrs. Maria P. Kouroupas, US Department of State, Mr. Fabrizio Panone (INTERPOL) and Mr. Laurent Pinot (WCO) are not only experts in their fields but also visionaries for the future of cultural heritage protection and preservation. They promote the e-documentation and protection of the past in such a way for its preservation for the generations to come.

We extend our thanks to all authors, speakers, and those persons whose labor, financial support, and encouragement made EuroMed2014 event possible. The international Program Committee, whose members represent a cross-section of archaeology, physics, chemistry, civil engineering, computer science, graphics and design, library, archive, and information science, architecture, surveying, history, and museology, worked tenaciously and finished their work on time. The staff of the IT Department at the Cyprus University of Technology helped with their local ICT and audio-visual support, especially Mr. Filippos Filippou, Mr. Costas Christodoulou, and Mr. Stephanos Mallouris. We would also like to express our gratitude to all the organizations supporting this event and our co-organizers, the European Commission scientific and policy officers of the H2020 Marie Skłodowska-Curie Programme, the director general of Europeana Mrs. Jill Cousins, the Getty Conservation Institute and World Monuments Fund, the Cyprus University of Technology, the Ministry of Energy, Commerce, Industry, and Tourism, especially the permanent secretary, and Digital Champion Dr. Stelios Himonas and Mr. Nikos Argyris, the Ministry of Education and Culture and particularly Minister Dr. Costas Kadis, the director of the Cultural Services Mr. Pavlos Paraskevas, the Department of Antiquities in Cyprus, all the members of the Cypriot National Committee for e-documentation and e-preservation in cultural heritage, and finally our corporate sponsors, CableNet Ltd., the Cyprus Tourism Organization, the Cyprus Postal Services, the Cyprus Handicraft Center, and Dr. Kyriakos Themistokleous from the Cyprus Remote Sensing Society, who provided services and 'gifts of kind' that made the conference possible.

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October 2014

Marinos Ioannides
Nadia Magnenat-Thalmann
Eleanor Fink
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Standards, Metadata, Ontologies and Semantic Processing in Cultural Heritage

Data Management and Visualisation/Presentation of Cultural Heritage Content

From a Model of a City to an Urban Information System: The SIUR 3D of the Castle of Pietrabuona

Duccio Troiano[1], Andrés García Morro[2], Alessandro Merlo[1], and Eduardo Vendrell Vidal[2]

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Abstract. Despite extensive research having been conducted on the subject, the problem of three-dimensional information systems for historical cities is actually still unresolved. In addition, commercially available software seems to be increasingly aiming at a quick development of unspecific urban settings, rather than at a metrically and perceptively faithful representation of reality. In this scenario, the SIUR 3D software (*Sistema Informativo URbano tridimensionale*) is based on a management structure that links an interactive, photorealistic and metrically reliable model of a city with a qualitative database of the historical, archaeological and material scope of an architectural part. Such application uses the Unity 3D game engine for geometrical models management and is equipped for online data sharing.

Keywords: 3D GIS, game engine, laser scanner, urban survey, semantic models, simplified models, UV mapping, normal mapping, computer programming.

1 Introduction

Located north of *Pescia*, a Tuscan town bordering with the ancient domains of Florence and Lucca, the *Valleriana* valley is a geographical unit, run through by two valleys (*Avellanita* and *Arriana* valleys), ruled over by rectorates in the past, and by an important stream.

The historical relevance of this landscape is due to a substantial amount of villages, most of them built in the 10^{th} century for defensive purposes, which eventually grew into *castella*, i.e. settlements with one or more circles of walls, with churches, fortifications and large estates, as well as people's homes, within them. Owing to the need to monitor such heritage (ten castles, including the surrounding villages), since 2007 DiDA (Dipartimento di Architettura dell'Università degli Studi di Firenze) has been conducting a number of surveys in the villages of *Aramo*, *Sorana* and *Pietrabuona*.

As well as documenting the processes through which such villages were born and evolved through the centuries, the aim of all such surveys is providing the conservation

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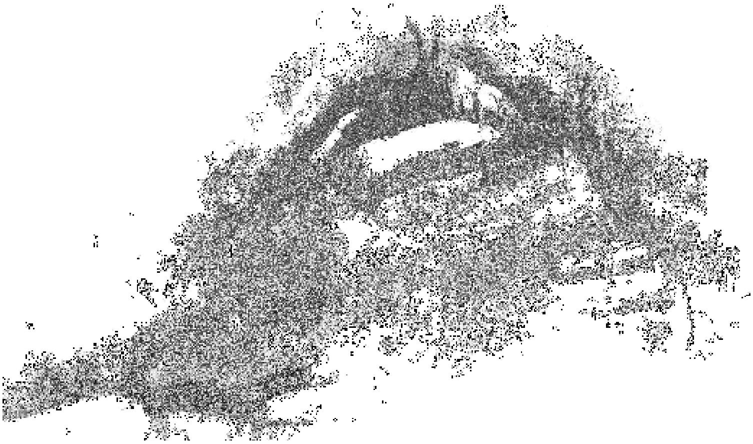

Fig. 1. Point-cloud survey of *Pietrabuona* Castle

authorities with a cultural and operational tool for a conservation, management and improvement policy.

This goal was achieved by means of a “combined” survey, i.e. a methodological approach that relies on a number of available tools (both, direct and digital) for a documentation of the urban environment (façades, streets and pavements, monuments, etc.).

In this way, a survey can provide a wide range of results, which would be hardly manageable by commercial software tools (e.g. *Autodesk Infrastructure Modeller* or *Esri City Engine*) or by a conventional approach based on 2D geometrical forms. Therefore, Università degli Studi di Firenze (DiDA: Dipartimento di Architettura) and the Universitat Politècnica de València (Instituto de Automàtica e Informática Industrial, ai2) joined forces to develop specific software (called SIUR 3D - URban Information Systems), which can manage the volume of measured data in a virtual 3D environment.

It is a real approach to a GIS 3D system, through which the results of a survey of urban environmental quality are accurately matched with 3D models. The resulting application may be used to review data and immediately match them to their geometrical representation and its geo-information.

2 Survey Data Management for Use of SIUR

2.1 Model Used as a Geometrical Base for a Management System

A laser scanner unit and a total station were used for a digital survey of the Castle of *Pietrabuona*. The scanning survey (using a Faro Photon laser scanner with phase-shift technology) was divided into 117 stations. Such stations provided a set of point clouds for the next phase, containing a total of 1,054 thousand millions points.

Before they can be integrated in a 3D SIUR, point clouds must be filtered, transformed and hierarchized through a procedure which includes the following steps and whose outcome is a continuous mesh model of the urban environment: 1 – The aligned point clouds of the whole conglomeration are subdivided into homogeneous sections that are easily and univocally identified; 2 – The identified sections of the total cloud model are exported to create high-poly models; 3 – Retopology[1] of high-poly models to build low-poly model surfaces that are easily manageable in real-time 3D applications; 4 – Surface texturing by normal and diffuse-colour maps; 5 – All modelled sections are linked together to recreate the urban environment.

Each phase is distinctive and subdivided for the following purposes: 1 – Models to be geometrically subdivided into consistent groups, associable with data from the database; 2 – Models to be compared with the laser scanner survey for accuracy; 3 – Photorealistic final model; 4 – Model to be used in online real-time applications.

Here, we will not go through all the stages in the process; however, two concepts are worth mentioning.

The first one is about the subdivision of the model, which was based on the same hierarchy as that used to store information in the database. Only through a highly hierarchized structure can one-to-one links be made between the numerical features of the database (referenced to reports on urban environmental quality) and the geometrical sections of the model[2]. Based on such approach, which is specific to GIS and digital databases, the built-up urban area was divided into blocks, each block into buildings (the smallest surveying unit, usually matching a cadastral entry), each building into façades, and so on, through to the architectural details. Specific sections of the model were matched with a branch of such tree-like structure, as the direct consequence of a semantic analysis of the town, and associated with matching data from the database.

The second concept is about control of geometrical errors introduced in the final model versus the original data, as the process moves from a raw datum taking up about 26 Gb of a disk (21 Gb for a laser scanner survey, 5 Gb for a photo survey) to a final processing of just 157 Mb (45 Mb for a poly model, 112 Mb for texture colour and normal maps).

To achieve this without altering the geometric-dimensional features of the architectures, retopology was the selected technique. Such technique involves the creation of a simplified polygonal geometry superimposed on a high-poly model. Such simplified geometry was improved from a perceptive point of view by using normal maps from baking operations[3] to texture from high-poly models. Normal maps, which show the angle of reflection of light on low-poly in the rendering process, recreate the perceived texture of brickwork that can be found in about 80% of the buildings of *Pietrabuona*.

As to the quality of the final model compared with the acquired data, the picture below offers a review of the errors introduced in each phase after the transformation of the point cloud into mesh high-poly. In particular, the diagram of the model of the eastern façade of the oratory of *San Michele* shows a deviation between the retopology

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1 This term stands for the procedure by which a triangular high-poly model is superimposed on a mainly quadrangular low-poly model, with a pre-set level of accuracy. The viewing of such models can be managed in real-time by rendering game engines such as *Unity 3D*.

2 This approach to modeling may also be defined as “semantic”, i.e. aiming at identifying basic constituent items in an organic system [3].

3 In computer graphics, texture baking is the process whereby information is taken from the scene and transferred into an object’s UV space.

Fig. 2. The former town hall of *Pietrabuona*. On the left, a rendering with a normal map applied to a low-poly model. On the right, a rendering with a normal map and a colour map.

surface and the matching point cloud (direct comparison between the finished work and the source). A chromatic analysis of the deviation diagram shows that the simplified model of such sector introduced a maximum error of 1.5-2 cm (in about 82% of the analysed model, the error ranges between 0 and 10 mm, while the average error is just 0.8 mm). Such figure is perfectly compatible with an urban type of survey and with our objectives.

The last step in the production of the final model is the application of diffused colour, making the model perfectly realistic. A photo campaign was carried out to get the texture. The aim was to cover each façade with at least 4 pictures, so as to fill up most of the occlusions caused by leaning elements (terraces, lighting bodies, etc.). External lens calibration parameters were calculated by finding homologous points in the image and in the model, so that every single photogram could be re-projected on low-poly surfaces.

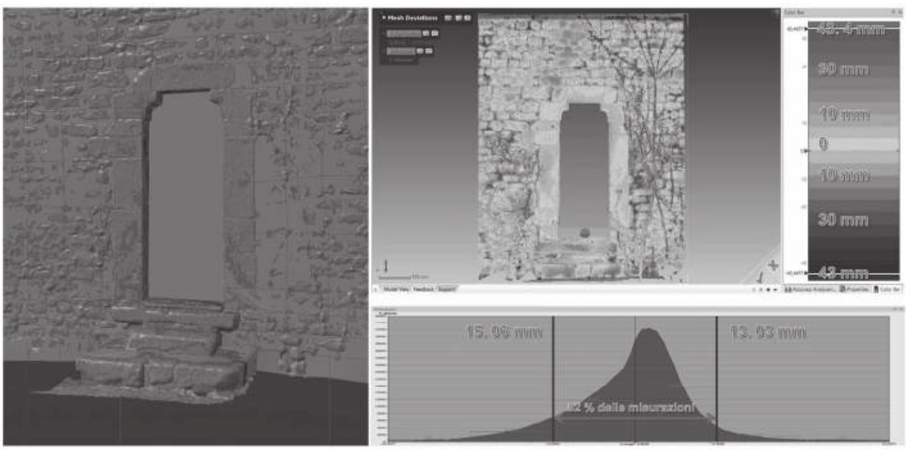

Fig. 3. Oratory of *San Michele*. Analysis of retopology-induced error

2.2 Qualitative Survey of the Built-Up Area

Over the past two years, the Castle of *Pietrabuona* has been the focus of several studies, in an effort to document the process through which the early medieval built-up area was born and evolved over the centuries.

The ancient fortress, the churches and the walls have been extensively investigated. In addition, assumptions have been made about the urban development of the entire settlement, from its foundation to this day. Such analysis was supported by a detailed monitoring of the quality of the built-up environment (kind and quality of public places, gardens and urban fittings). Such survey was the first of its kind to be put into the 3D SIUR and deserves to be separately addressed, to explain its contents and hierarchic structure (the same as the one used to subdivide the model). The Castle was divided into its building units (special and basic building units) and into urban parts (squares and streets), each one associated with a specific database.

In the Buildings database, also designed to fulfil the requirements of the city planning department of *Pescia*[4], the built-up area was subdivided into blocks, buildings and façades. The latter, that are the core of the database, are essential to file lots of elements, some of which are key to urban environmental quality. Actually, any façade is matched with one or more types of walling, openings and windows[5], terraces and general overhangs, and the quality and shape of the eaves. Anything that is stored in the database has specific fields, which define potential decay and the option to add any material (drawings, pictures, notes and other documents).

The urban database contains information about streets and squares, with the option to add any kind of paving, potential decay, and so on. The latter database, even if less complex than the previous one, plays a key role in that it contains information about the public fittings of the built-up area, such as urban green areas and lighting.

Stored at first on hardcopy, then in an *Access* database based on the cadastral plan of *Pietrabuona* with *Autocad map 3D*, now such data shall be put into the 3D SIUR, the structure of which has already been tested on some areas of the Building Quality database.

3 SIUR 3D: Software Architecture

One of the key factors in a three-dimensional GIS system, such as *Pietrabuona*'s SIUR 3D, is easy access to data through the web. Users can have access to such data from any computer connected to Internet, thus dramatically reducing the time it would take to find such data, compared with ten or so years ago. A potential increase in the number of users would also mean that users may have direct control on the quality of such data, thus triggering a process that would generally improve the quality of such information.

To make sure that related information may be shared, *Pietrabuona*'s SIUR 3D is based on the well-known *client-server* approach.

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[4] The local government was involved in the project as a potential user of such software.

[5] The SIUR testing revolved around the Stone and Plastered Masonry areas.

The word *client* usually means the people who have access to specific services. In SIUR 3D, clients may be divided into *users* (those that have access to data but can only view and consult them) and *administrators* (those that may view and change such data).

Each client category matches two specific interfaces for access to information, called *user interface* and *administrator interface.*

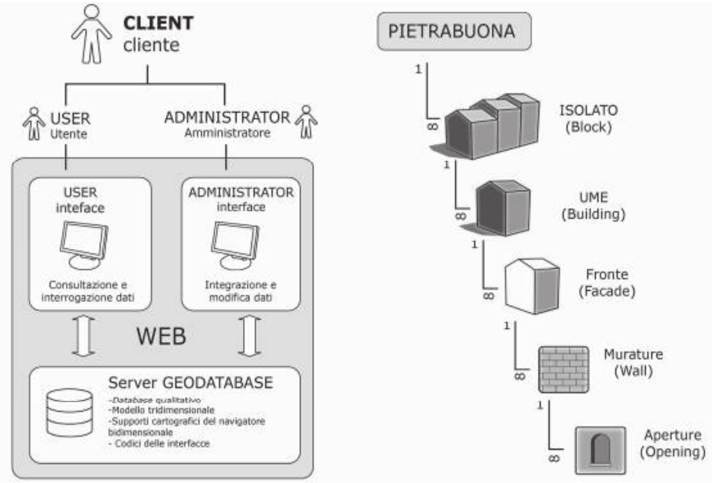

Fig. 4. SIUR 3D: software architecture and semantic decomposition of the database

The word *server* means refers to an IT system consisting of hardware and software that can provide services to the system's clients. Namely, the server of the SIUR 3D will store the model of the Castle linked to a qualitative database and will manage access to the stored information based on the client's credentials. In addition, the server shall always be responsible for installing and updating the *Unity 3D player* on the client's personal computer.

3.1 Administrator Interface

The *administrator interface* is a veritable window opening onto the heart of SIUR 3D, its data stored in the server and consisting of the three-dimensional model of the Castle and the information stored in the urban quality database[6]. The tools provided by the interface may be used to add, change, complete or replace such elements.

The features of the application are viewed on screen, divided into three sections: on the left, the "browser panel", the "data panel" in the middle, and the "model panel" on the right.

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[6] The software consists of a standalone application, to be applied to the user's computer. Once installed, the system automatically downloads and installs the *Unity 3D Player*, a free application for three-dimensional, dynamic viewing of the models uploaded into the system.

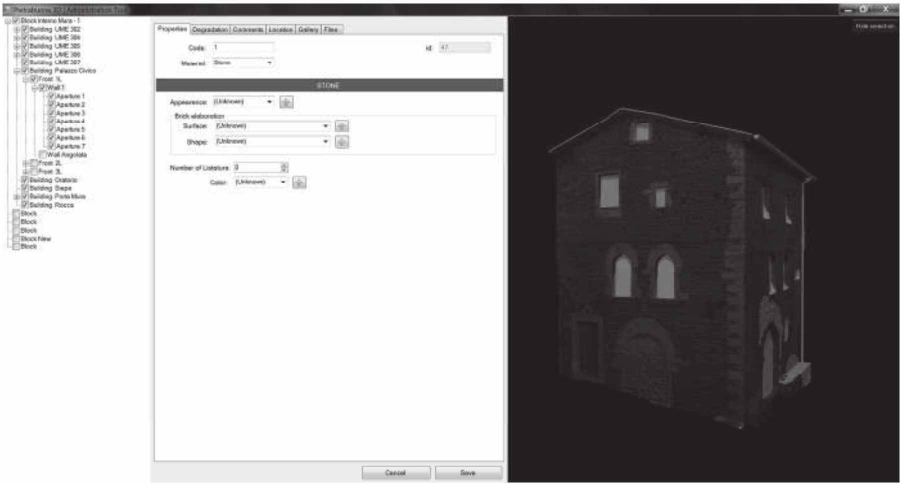

Fig. 5. Administrator interface

The browsing panel has a tree-like structure, with the block entity at the top. By pressing the right button of the mouse on the block tag, the block may be matched with the building units (UME); by pressing the right button again on a UME, multiple façades may be added to it, then each façades may be matched with multiple kinds of walling, and finally each walling may be matched with the openings. The elements created through this procedure look like empty boxes, which, by means of the data panel, may be matched with parts of the three-dimensional model and information for the database. The items in the browsing panel may be explored with +/– on the left of the tag of each element: the + key may be used to explore the elements that are associated with a specific item, the – key may be used to reduce the view of such elements down to zero for a better view and summary of the entire panel. While selecting an item in the browsing panel, the data and model panels will jointly synchronise with such item, so the filling-in process will be user-friendly, always supported by the visual exploration provided by the model.

The centrally-placed data panel is the actual interface of the qualitative database hosted by the server: it is organised in tables (the so-called *data tabs*) which may be consulted by clicking on one of the tags at the top of the panel. The tables, which may be used to add information and link it to parts of the three-dimensional model imported as Unity assets, are: *properties, degradation*, *comments*, *location, gallery, file.*

The structure of the *properties* table automatically changes depending on the item selected in the browsing panel: by clicking on a walling, the properties window will show boxes for the kind of walling, so one can choose whether to specify that such walling is e.g. plastered or exposed stone.

The other tables have the same structure for every item, since no special difference is required in that case. Such tables may be used to complete the overall information of an item, including the option to add pictures, notes on decay, text documents or any other attached file.

To complete the *administrator interface*, a model box on the right offers a dynamic view of such item[7]: it has been specifically decided, at the design stage, that it should never show the entire built-up area but just the part of the model that has been selected in the browsing box, so that the item the user is working at is always clearly visible to him/her.

3.2 User Interface

The tools provided by the *administrator interface* are just for adding data. The synthetic capabilities that are specific to any two- or three-dimensional GIS, such as querying and databased theme-documents, are integral instead to the *user interface*. As it must engage in an interpretative reading of information from the database, such software features much more complex tools than those we have mentioned so far. Such complexity is basically due to the three-dimensional nature of the graphics in the SIUR 3D, so it was designed with a view to finding solutions that could help users clearly and synthetically use and measure the model.

To do this, some tools were designed to make viewing more flexible, such as the option to hide the items or separate them from the context. Pride of place was given to the orthogonal viewing of the model, with the option to automatically create perspectives of urban backgrounds, or even develop them for full-size viewing at all times. As three-dimensional viewing may often be unsuitable for an interpretative reading of an urban context, for example in the composition-architectural survey of a façade or in the study of a case of decay, the *user interface* features a customisable two-dimensional plan (cadastral plan – ortho-photo – ground-floor plan), which acts as a sort of connecting link between data from the Castle's database and its three-dimensional representation.

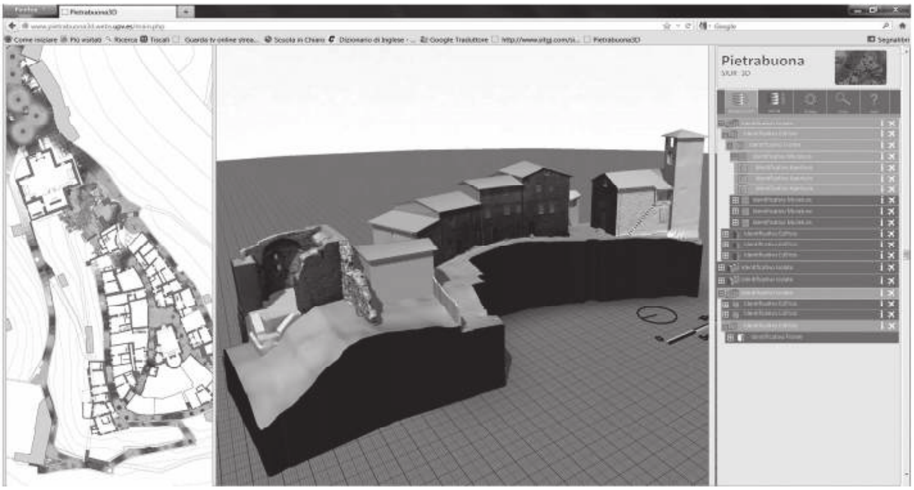

Fig. 6. User interface

[7] Viewing is provided by the *Unity 3D Player* application.

Generally speaking, the planned layout of the application involves three on-screen boxes that can be freely sized. On the left, the *2D view* box, as we mentioned before, shows the layout of the Castle. In the centre, the *3D view* box contains an interactive, navigable model of the Castle. On the right, the *contents* box provides tools that may be used to explore and query the qualitative database.

The features of the software have been designed by defining the specific controls of each box, which have been described in terms of the set of operations the user must perform to use the tool, as well as in terms of the reply given by the software to the user in each box. In this respect, note that the three boxes have been designed to work in perfect synchrony: this means, for example, that if you select a specific building in the tree-like browser of the *contents* view, the 3D view camera will focus on the one in the item (*fly to* control), while the 2D views will zoom on to such selected item.

4 Conclusions

When developing computer-assisted documentation and management systems for historical urban contexts, as the case of SIUR 3D, a synergic relationship between surveyors/architects and information technologists is a prerequisite to find effective solution to real problems. At the design stage, after defining a “range of requirements”, both professionals jointly choose the best strategies to solve any problem, from an IT point of view and in terms of the strategies required to view and represent both Architecture and Environment.

The first release of the *administrator interface* in SIUR 3D was found to be user-friendly and generally ‘well behaved’. However, the *user interface,* although fully designed, must still be accomplished in some respects[8]. Its development is still in progress and some features, including measurement tools (distance, area, volume…), as well as querying and query-viewing features.

Finally, the tests found the entire system to be extremely flexible, suggesting it might be easily applied to contexts other than the tested one, with options ranging from archaeological surveys to the analysis of urban contexts of any age.

SIUR 3D can be used in the future as an extension or complement tool for commercial solutions such as Google Maps, in order to analyse historical buildings or urban neighbourhoods, allowing the user to focus on details or perform advanced search for 3D elements.

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[8] The first release of the *user interface* is currently available at: `http://pietrabuona3d.webs.upv.es/main.php`.

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