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Marinos Ioannides  
Nadia Magnenat-Thalmann  
Eleanor Fink Roko Žarnić  
Alex-Yianing Yen Ewald Quak (Eds.)

# Digital Heritage

Progress in Cultural Heritage:  
Documentation, Preservation,  
and Protection

5th International Conference, EuroMed 2014  
Limassol, Cyprus, November 3–8, 2014  
Proceedings

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## Volume Editors

Marinos Ioannides

Cyprus University of Technology, Limassol, Cyprus

E-mail: marinos.ioannides@cut.ac.cy

Nadia Magnenat-Thalmann

University of Geneva, Switzerland

E-mail: thalmann@miralab.ch

Eleanor Fink

2360 N. Vernon Street, Arlington, VA 22207, USA

E-mail: eleanorfink@earthlink.net

Roko Žarnić

University of Ljubljana, Slovenia

E-mail: roko.zarnic@fgg.uni-lj.si

Alex-Yianing Yen

China University of Technology, Taipei, Taiwan

E-mail: alexyen@cute.edu.tw

Ewald Quak

Tallinn University of Technology, Estonia

E-mail: ewald.quak@cs.ioc.ee

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# Preface

Welcome to the proceedings of the 5<sup>th</sup> 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 5<sup>th</sup> 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 Scopigno (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. Filippou 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-Thalman  
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# Table of Contents

## Digital Data Acquisition Technologies and Data Processing in Cultural Heritage

Automatic Registration of Non-overlapping Laser Scans Based on a Combination of Generated Images from Laser Data and Digital Images in One Bundle . . . . .	1
<i>Wassim Moussa and Dieter Fritsch</i>	
Colour and Space in Cultural Heritage: Key Questions in 3D Optical Documentation of Material Culture for Conservation, Study and Preservation . . . . .	11
<i>Frank Boochs, Anna Bentkowska-Kafel, Christian Degrigny, Maciej Karaszewski, Ashish Karmacharya, Zoltan Kato, Marcello Picollo, Robert Sitnik, Alain Trémeau, Despoina Tsiafaki, and Levente Tamas</i>	
In the Pursuit of Perfect 3D Digitization of Surfaces of Paintings: Geometry and Color Optimization . . . . .	25
<i>Maciej Karaszewski, Krzysztof Lech, Eryk Bunsch, and Robert Sitnik</i>	
Architectural Historical 4D Documentation of the Old-Segeberg Town House by Photogrammetry, Terrestrial Laser Scanning and Historical Analysis . . . . .	35
<i>Thomas P. Kersten, Nils Hinrichsen, Maren Lindstaedt, Christoph Weber, Kristin Schreyer, and Felix Tschirschwitz</i>	
Capturing the Sporting Heroes of Our Past by Extracting 3D Movements from Legacy Video Content . . . . .	48
<i>Jon Goenetxea, Luis Unzueta, Maria Teresa Linaza, Mikel Rodriguez, Noel O'Connor, and Kieran Moran</i>	
A High Speed Dynamic System for Scanning Reflective Surface with Rotating Polarized Filters . . . . .	59
<i>Ryo Ogino, Jay Arre Toque, Pengchang Zhang, and Ari Ide-Ektessabi</i>	
Orthoimage of Asclepieion at the Ancient Messene from UAV Images Applying Dense Image Matching . . . . .	70
<i>Evangelos Maltezos and Charalabos Ioannidis</i>	
Innovation Technologies and Applications for Coastal Archaeological Sites” . . . . .	80
<i>Alessio Di Iorio, Dimitrios Biliouris, Lars Boye Hansen, and Antonella Canestro</i>	



Content-Based Filtering for Fast 3D Reconstruction from Unstructured Web-Based Image Data . . . . .	91
<i>Konstantinos Makantasis, Anastasios Doulamis, Nikolaos Doulamis, Marinos Ioannides, and Nikolaos Matsatsinis</i>	
Semi-supervised Image Meta-filtering in Cultural Heritage Applications . . . . .	102
<i>Eftychios Protopapadakis, Anastasios Doulamis, and Nikolaos Matsatsinis</i>	
Semi-automatic Segmentation and Modelling from Point Clouds towards Historical Building Information Modelling . . . . .	111
<i>Hélène Macher, Tania Landes, Pierre Grussenmeyer, and Emmanuel Alby</i>	
From a Model of a City to an Urban Information System: The SIUR 3D of the Castle of Pietrabuona . . . . .	121
<i>Duccio Troiano, Andrés García Morro, Alessandro Merlo, and Eduardo Vendrell Vidal</i>	
Beyond Software. Design Implications for Virtual Libraries and Platforms for Cultural Heritage from Practical Findings . . . . .	131
<i>Sander Münster and Nikolas Prechtel</i>	
Cultural Heritage Information Systems State of the Art and Perspectives . . . . .	146
<i>Barbara Vodopivec, Rand Eppich, and Roko Žarnić</i>	
Distribution of Cultural Content through Exploitation of Cryptographic Algorithms and Hardware Identification . . . . .	156
<i>Harris E. Michail, Constantinos Louca, Dimitris Gavrilis, Andreas Gregoriades, Lazaros Anastasiou, and Marinos Ioannides</i>	
Beyond Crude 3D Models: From Point Clouds to Historical Building Information Modeling via NURBS . . . . .	166
<i>Daniela Oreni, Raffaella Brumana, Fabrizio Banfi, Luca Bertola, Luigi Barazzetti, Branka Cuca, Mattia Previtali, and Fabio Roncoroni</i>	
M3art: A Database of Models of Canvas Paintings . . . . .	176
<i>Jan Blažek, Jindřich Soukup, Barbara Zitová, Jan Flusser, Janka Hradilová, David Hradil, and Tomáš Tichý</i>	
Bridging Archaeology and GIS: Influencing Factors for a 4D Archaeological GIS . . . . .	186
<i>Berdien De Roo, Kristien Ooms, Jean Bourgeois, and Philippe De Maeyer</i>	

## The e-Documentation of Intangible Cultural Heritage

Analyzing Taiwanese Indigenous Folk Dances via Labanotation and Comparing Results from Interdisciplinary Studies . . . . .	196
<i>Huaichin Hu, Rayuan Tseng, Chyicheng Lin, Likuo Ming, and Katsushi Ikeuchi</i>	
LMA-Based Motion Retrieval for Folk Dance Cultural Heritage . . . . .	207
<i>Andreas Aristidou, Efsthios Stavrakis, and Yiorgos Chrysanthou</i>	

## Standards, Metadata, Ontologies and Semantic Processing in Cultural Heritage

Ontology-Driven Processing and Management of Digital Rock Art Objects in IndianaMAS . . . . .	217
<i>Daniela Briola, Vincenzo Deufemia, Viviana Mascardi, Luca Paolino, and Nicoletta Bianchi</i>	
How Linked Open Data Can Help in Locating Stolen or Looted Cultural Property . . . . .	228
<i>Eleanor E. Fink, Pedro Szekely, and Craig A. Knoblock</i>	
Automatic Enrichments with Controlled Vocabularies in Europeana: Challenges and Consequences . . . . .	238
<i>Juliane Stiller, Vivien Petras, Maria Gäde, and Antoine Isaac</i>	

## Data Management and Visualisation/Presentation of Cultural Heritage content

Along the Appian Way. Storytelling and Memory across Time and Space in Mobile Augmented Reality . . . . .	248
<i>Gunnar Liestøl</i>	
A Geometric Algebra Animation Method for Mobile Augmented Reality Simulations in Digital Heritage Sites . . . . .	258
<i>George Papaqiannakis, Greasidou Elissavet, Panos Trahanias, and Michalis Tsioumas</i>	
Interactive 3D Visualisation of Architectural Models and Point Clouds Using Low-Cost-Systems . . . . .	268
<i>Felix Tschirschwitz, Thomas P. Kersten, and Kay Zobel</i>	
3D Visualization via Augmented Reality: The Case of the Middle Stoa in the Ancient Agora of Athens . . . . .	279
<i>Styliani Verykokou, Charalabos Ioannidis, and Georgia Kontogianni</i>	

Between the Fragment and the Atlas: A Device for the Visualization and Documentation of the *Cité de l'Architecture et du Patrimoine* in Paris ..... 290  
*Fabrizio Gay and Matteo Ballarin*

**Innovative Technologies to Assess, Monitor, Restore and Preserve Cultural Heritage**

Using Heritage Risk Maps as an Approach for Estimating the Climate Impact to Cultural Heritage Materials in the Island of Taiwan ..... 300  
*Ping-Sheng Wu, Chun-Ming Hsieh, and Min-Fu Hsu*

Documentation and Evaluation of the Positive Contribution of Natural Ventilation in the Rural Vernacular Architecture of Cyprus ..... 310  
*Aimilios Michael, Maria Philokyprou, and Chrystalla Argyrou*

Shared Solutions to Tackle Restoration Restrictions and Requirements for Cultural Landscape and the Sustainable Conservation of Cultural Heritage ..... 321  
*Elena Gigliarelli and Giuliana Quattrone*

Preservative Approach to Study Encased Archaeological Artefacts ..... 332  
*Théophane Nicolas, Ronan Gaugne, Cédric Tavernier, Valérie Gouranton, and Bruno Arnaldi*

Microwave Assisted Preparation of Calcium Hydroxide and Barium Hydroxide Nanoparticles and Their Application for Conservation of Cultural Heritage ..... 342  
*Khaled M. Saoud, Imen Ibala, Dana El Ladki, Omar Ezzeldeen, and Shaukat Saeed*

Quality of Rural Life and Culture: Managing Change through the Identification of Good Practice, Pilot Implementation Projects and Evaluation ..... 353  
*Rand Eppich, Alexandra Kulmer, Juan Carlos Espada, Barbara Vodopivec, and Roko Žarnić*

**Accessing the Impact of EU Research, Development and Technology in the Digital Heritage Domain**

MAXICULTURE: Assessing the Impact of EU Projects in the Digital Cultural Heritage Domain ..... 364  
*Francesco Bellini, Antonella Passani, Francesca Spagnoli, David Crombie, and George Ioannidis*

## Digital Data Acquisition Technologies and Data Processing in Cultural Heritage

Characterisation of Spatial Techniques for Optimised Use in Cultural Heritage Documentation .....	374
<i>Ann-Kathrin Wiemann, Frank Boochs, Ashish Karmacharya, and Stefanie Wefers</i>	
Integration of Innovative Surveying Technologies for Purposes of 3D Documentation and Valorisation of St. Herakleidios Monastery in Cyprus .....	387
<i>Branka Cuca, Athos Agapiou, Andreas Kkolos, and Diofantos Hadjimitsis</i>	
More Than a Flight: The Extensive Contributions of UAV Flights to Archaeological Research – The Case Study of Curium Site in Cyprus ...	396
<i>Kyriacos Themistocleous, Athos Agapiou, Helen M. King, Nigel King, and D.G. Hadjimitsis</i>	
Accurate and Cost-Efficient 3D Modelling Using Motorized Hexacopter, Helium Balloons and Photo Modelling: A Case Study .....	410
<i>Britt Lonneville, Berdien De Roo, Cornelis Stal, Bart De Wit, Alain De Wulf, and Philippe De Maeyer</i>	
Combination of 3D Scanning, Modeling and Analyzing Methods around the Castle of Coatfrec Reconstitution .....	418
<i>Jean-Baptiste Barreau, Yann Bernard, Quentin Petit, Laurent Beuchet, Emilien Petit, Volker Platen, Ronan Gaugne, Julien Le Rumeur, and Valérie Gouranton</i>	
Design for Knowledge and Restoration: Instrumental Survey at Santa Maria in San Celso .....	427
<i>Angela Baila, Lorenzo Mazza, and Anna Anzani</i>	
Historic Center 3D Metric Documentation Updating by Low Cost Solution: The Lençóis Project .....	438
<i>Arivaldo Leão de Amorim, Gabriele Fangi, and Eva Savina Malinverni</i>	
Digital Survey and Material Analysis Strategies for Documenting, Monitoring and Study the Romanesque Churches in Sardinia, Italy .....	446
<i>Stefano Columbu and Giorgio Verdiani</i>	
3D Reconstruction of Saltanat Gate in Dolmabahce Palace .....	454
<i>Ovgu Ozturk Ergun, Bo Zheng, Bahtiyar Kaba, Huseyin Inan, Masataka Kagesawa, and Katsushi Ikeuchi</i>	
Architectural Perspectives Survey .....	463
<i>Riccardo Migliari, Marco Fasolo, Leonardo Baglioni, Marta Salvatore, Jessica Romor, and Matteo Flavio Mancini</i>	

3D Technologies for the Integrated Analysis of World Heritage: The Case of UNESCO's Škocjan Caves, Slovenia . . . . .	473
<i>Gregor Novakovič, Dimitrij Mlekuž, Luka Rozman, Aleš Lazar, Borut Peric, Rosana Cerkvenik, Karmen Peternelj, and Miran Erič</i>	
Integrated Application of Digital Technologies for Transmitting Values of Cultural Heritage in Remote Mountains . . . . .	482
<i>Yi-Jen Tseng, Tsung-Chiang Wu, and Sheng-Fa Hsu</i>	
<b>Innovative Graphic Applications and Techniques</b>	
Experimental BIM Applications in Archeology: A Work-Flow . . . . .	490
<i>Andrea Scianna, Susanne Gristina, and Silvia Paliaga</i>	
Bologna Porticoes Project: 3D Reality-Based Models for the Management of a Wide-Spread Architectural Heritage Site . . . . .	499
<i>Fabrizio Ivan Apollonio, Marco Gaiani, Federico Fallavollita, Massimo Ballabeni, and Sun Zheng</i>	
GAs and Evolutionary Design in Architectural Heritage-The Case of Islamic Architecture . . . . .	507
<i>Osama Mohammad Alrawi</i>	
Keeping the Equilibrium: The Static Aspects of the Restoration Project. The Case Study of the Mother Church of San Cataldo (Sicily) . . . . .	517
<i>Antonella Versaci, Alessio Cardaci, Davide Indelicato, and Luca Renato Fauzia</i>	
Giving Life to John Calvin the Reformer . . . . .	526
<i>Marlène Arévalo, Nedjma Cadi-Yazli, and Nadia Magnenat Thalmann</i>	
meSch – Material Encounters with Digital Cultural Heritage . . . . .	536
<i>Daniela Petrelli, Elena Not, Areti Damala, Dick van Dijk, and Monika Lechner</i>	
Playhist: Play and Learn History. Learning with a Historical Game vs An Interactive Film . . . . .	546
<i>Ainhoa Perez-Valle, Pablo Aguirrezabal, and Sara Sillaurren</i>	
Intelligent Interactive Applications for Museum Visits . . . . .	555
<i>Kemal Egemen Ozden, Devrim Unay, Huseyin Inan, Bahtiyar Kaba, and Ovgu Ozturk Ergun</i>	
Digital Archive System with 3D Web Portal Interface . . . . .	564
<i>Ryosuke Matsushita, Hiroshi Suita, and Yoshihiro Yasumuro</i>	

Presenting Cypriot Cultural Heritage in Virtual Reality: A User Evaluation .....	572
<i>F. Loizides, A. El Kater, C. Terlikas, A. Lanitis, and D. Michael</i>	

## 2D and 3D GIS in Cultural Heritage

Research on the GIS as a Communication Platform in the Risk Management of Traditional Settlement .....	580
<i>Alex Ya-Ning Yen and Chin-fang Cheng</i>	

An Application of G.I.S on Integrative Management for Cultural Heritage- An Example for Digital Management on Taiwan Kinmen Cultural Heritage .....	590
<i>Wun-Bin Yang, Hung-Ming Cheng, and Ya-Ning Yen</i>	

Geospatial Technologies for the Built Heritage Management: Experiences in Sardinia, Italy .....	598
<i>Michele Campagna, Maddalena Achenza, Yuri Iannuzzi, and Chiara Cocco</i>	

Worthy Outcomes from a System Advancing the Sharing of CH Data and Stakeholders' Relations .....	606
<i>Antonia Spanò, Elena Cerutti, Carla Bartolozzi, and Francesco Novelli</i>	

## Innovative Technologies to Assess, Monitor, Restore and Preserve Cultural Heritage

Digital Morphometric Survey for Documentation, Conservation and Restoration Works: The MUDI Project .....	617
<i>Roberto Di Giulio, Marcello Balzani, Federica Maietti, and Federico Ferrari</i>	

Recovery of Fragile Objects from Underwater Archaeological Excavations: New Materials and Techniques by SASMAP Project .....	625
<i>Barbara Davidde Petriaggi, David John Gregory, and Jørgen Dencker</i>	

The VernArch Digital Database Project: Documentation and Protection of the Vernacular Architecture of Cyprus .....	635
<i>Maria Philokyprou</i>	

Preservation of a Computer-Based Art Installation .....	643
<i>Franc Solina, Gregor Majcen, Narvika Bovcon, and Borut Batagelj</i>	

A Study on Spatial Changes within Rukai Indigenous Settlements during the Japanese Colonial Era .....	651
<i>Sheng-Fa Hsu, Yi-Jen Tseng, and Min-Fu Hsu</i>	



Informing Historical Preservation with the Use of Non-destructive Diagnostic Techniques: A Case Study at Ecab, Quintana Roo, Mexico .....	659
<i>Michael Hess, Dominique Meyer, Aliya Hoff, Dominique Rissolo, Luis Leira Guillermo, and Falko Kuester</i>	
Assessment of Structural Natural Frequencies and Application in the Calibration of FEM Models and Structural Health Monitoring .....	669
<i>Davor Uglešić and Ante Uglešić</i>	
Restoration of the Dome of St. James's Cathedral in Šibenik .....	678
<i>Davor Uglešić and Miljenko Domijan</i>	
Heritage Landscape Conservation and Development .....	687
<i>Jia Guo</i>	
Non-invasive Materials Analysis Using Portable X-ray Fluorescence (XRF) in the Examination of Two Mural Paintings in the Catacombs of San Giovanni, Syracuse .....	697
<i>Samantha Stout, Antonino Cosentino, and Carmelo Scandurra</i>	
The Madonna of the Goldfinch by Raphael: Chamera of Perception ....	706
<i>Perla Gianni Falvo</i>	

## **Standards, Metadata, Ontologies and Semantic Processing in Cultural Heritage**

Ontology-Driven Visual Browsing of Historical Industrial Archives .....	716
<i>Monica De Martino, Marina Monti, Simone Pastorino, and Chiara Rosati</i>	
Graph Based Keyword Spotting in Medieval Slavic Documents – A Project Outline .....	724
<i>Kaspar Riesen, Darko Brodić, Zoran N. Milivojević, and Čedomir A. Maluckov</i>	

## **Data Management and Visualisation/Presentation of Cultural Heritage Content**

Design Considerations for Implementing an Interactive DigiLog Book ...	732
<i>Taejin Ha and Woontack Woo</i>	
Modeling the Past Online: Interactive Visualisation of Uncertainty and Phasing .....	740
<i>Joanna S. Smith, Szymon M. Rusinkiewicz, Silvana Alberti, Junjun Chen, Maricela Coronado, Garrett Disco, Anastasia Georgiou, Tamara Pico, George Touloumes, and Gina Triolo</i>	

Logboats: A Global Symbolic Content for New Reflections on the Protection of World Heritage in the Future with the Help of Cutting Edge Technology . . . . .	749
<i>Miran Erič</i>	
QRCODE and RFID Integrated Technologies for the Enhancement of Museum Collections . . . . .	759
<i>Mincolelli Giuseppe, Biancardi Michela, Fabbri Matteo, Feriotto Chiara, Massarente Alessandro, Munerato Stefano, and Raco Fabiana</i>	
<b>The e-Documentation of Intangible Cultural Heritage</b>	
Multilingual Specialist Glossaries in a Framework for Intangible Cultural Heritage . . . . .	767
<i>Maria Teresa Artese and Isabella Gagliardi</i>	
Fuzzy Archives. What Kind of an Object Is the Documental Unit of Oral Archives? . . . . .	777
<i>Calamai Silvia, Biliotti Francesca, and Bertinetto Pier Marco</i>	
<b>Accessing the Impact of EU Research, Development and Technology in the Digital Heritage Domain</b>	
The Digitization Age: Mass Culture Is Quality Culture. Challenges for Cultural Heritage and Society . . . . .	786
<i>Valentina Bachi, Antonella Fresca, Claudia Pierotti, and Claudio Prandoni</i>	
From Europeana Cloud to Europeana Research: The Challenges of a Community-Driven Platform Exploiting Europeana Content . . . . .	802
<i>Agiatis Benardou, Costis Dallas, and Alastair Dunning</i>	
Using ICT in Cultural Heritage, Bless or Mess? Stakeholders' and Practitioners' View through the eCultValue Project . . . . .	811
<i>Yannis Ioannidis, Eleni Toli, Katerina El Raheb, and Maria Boile</i>	
Tangible versus Intangible in e-Learning on Cultural Heritage: From Online Learning to On-site Study of Historic Sites . . . . .	819
<i>Anna Lobovikov-Katz, Antonia Moropoulou, Agoritsa Konstanti, Pilar Ortiz Calderón, Rene Van Grieken, Susannah Worth, JoAnn Cassar, Roberta De Angelis, Guido Biscontin, and Francesca Caterina Izzo</i>	
<b>Author Index . . . . .</b>	<b>829</b>

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

Duccio Troiano<sup>1</sup>, Andrés García Morro<sup>2</sup>, Alessandro Merlo<sup>1</sup>,  
and Eduardo Vendrell Vidal<sup>2</sup>

<sup>1</sup> Università degli Studi di Firenze, DiDA: Dipartimento di Architettura,  
Via della Mattonaia 14, 50121 Firenze, Italia

duccio.troiano@gmail.com, alessandro.merlo@unifi.it

<sup>2</sup> Universidad Politécnica de Valencia, Instituto de Automática e Informática Industrial: ai2,  
Camino de Vera, s/n, 46022 Valencia, Spain  
angarmor@inf.upv.es, even@upv.es

**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.

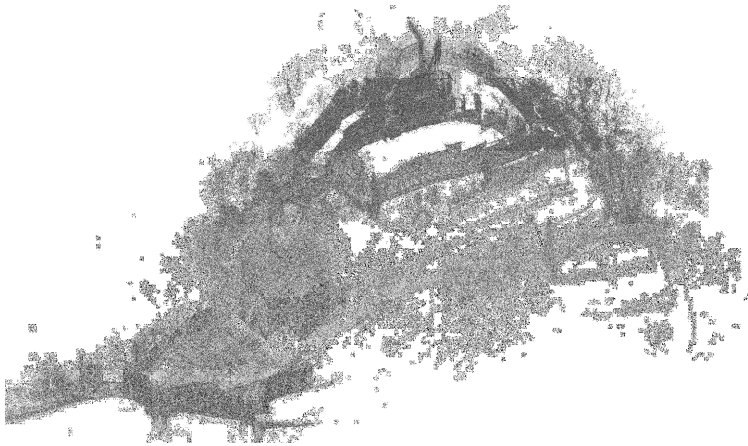
**Keywords:** 3D GIS, game engine, laser scanner, urban survey, semantic models, simplified models, UV mapping, normal mapping, computer programming.

## 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<sup>th</sup> 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



**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 Informàtica 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<sup>1</sup> 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<sup>2</sup>. 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<sup>3</sup> 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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<sup>1</sup> 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*.

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

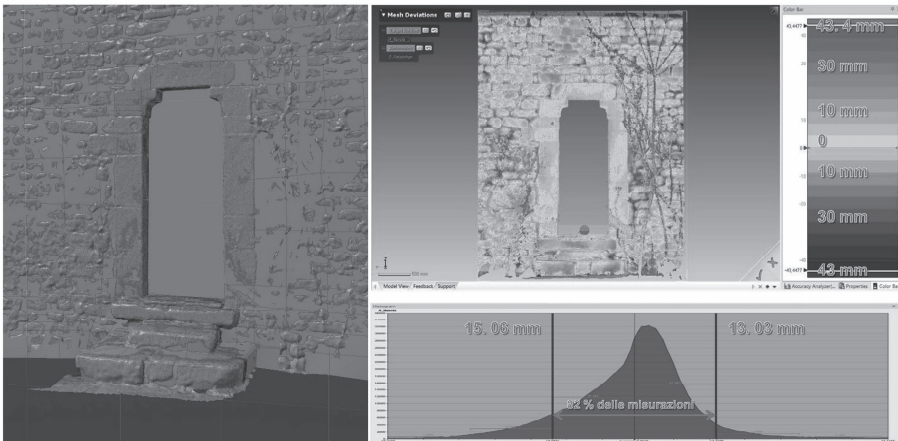
<sup>3</sup> In computer graphics, texture baking is the process whereby information is taken from the scene and transferred into an object’s UV space.



**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 hierarchical 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*<sup>4</sup>, 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<sup>5</sup>, 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.

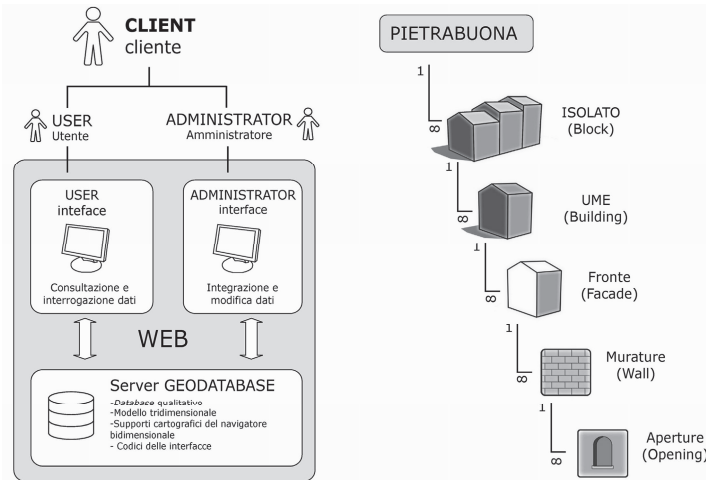
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<sup>4</sup> The local government was involved in the project as a potential user of such software.

<sup>5</sup> 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<sup>6</sup>. 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.

<sup>6</sup> 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.

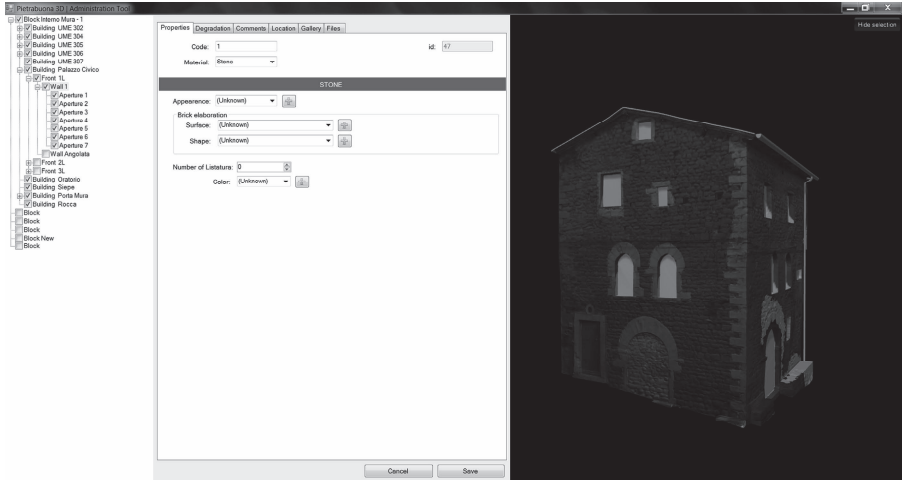


Fig. 5. Administrator interface

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<sup>7</sup>: 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.

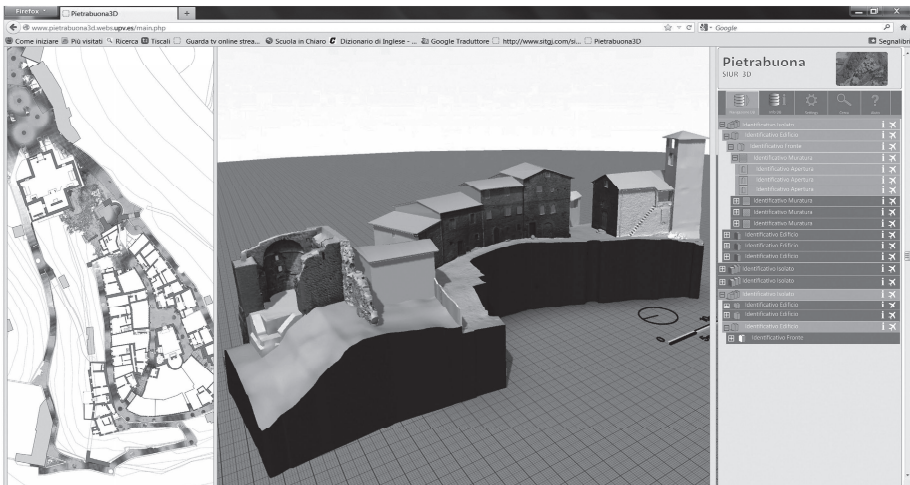


Fig. 6. User interface

<sup>7</sup> 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<sup>8</sup>. 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.

**Acknowledgments.** We would like to thank the Caripit Foundation and the Bank of Pescia, without whose support this research would not have been possible, and the local government of Pescia.

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<sup>8</sup> The first release of the *user interface* is currently available at:  
<http://pietrabuona3d.webs.upv.es/main.php>.

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