

LNCS 10058

Marinos Ioannides · Eleanor Fink
Antonia Moropoulou · Monika Hagedorn-Saupe
Antonella Fresa · Gunnar Liestøl
Vlatka Rajcic · Pierre Grussenmeyer (Eds.)

Digital Heritage

Progress in Cultural Heritage:
Documentation, Preservation,
and Protection

6th International Conference, EuroMed 2016
Nicosia, Cyprus, October 31 – November 5, 2016
Proceedings, Part I



 Springer

1
Part I

Commenced Publication in 1973

Founding and Former Series Editors:

Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

Editorial Board

David Hutchison

Lancaster University, Lancaster, UK

Takeo Kanade

Carnegie Mellon University, Pittsburgh, PA, USA

Josef Kittler

University of Surrey, Guildford, UK

Jon M. Kleinberg

Cornell University, Ithaca, NY, USA

Friedemann Mattern

ETH Zurich, Zurich, Switzerland

John C. Mitchell

Stanford University, Stanford, CA, USA

Moni Naor

Weizmann Institute of Science, Rehovot, Israel

C. Pandu Rangan

Indian Institute of Technology, Madras, India

Bernhard Steffen

TU Dortmund University, Dortmund, Germany

Demetri Terzopoulos

University of California, Los Angeles, CA, USA

Doug Tygar

University of California, Berkeley, CA, USA

Gerhard Weikum

Max Planck Institute for Informatics, Saarbrücken, Germany

More information about this series at <http://www.springer.com/series/7409>

Marinos Ioannides · Eleanor Fink
Antonia Moropoulou · Monika Hagedorn-Saupe
Antonella Fresca · Gunnar Liestøl
Vlatka Rajcic · Pierre Grussenmeyer (Eds.)

Digital Heritage

Progress in Cultural Heritage:
Documentation, Preservation,
and Protection

6th International Conference, EuroMed 2016
Nicosia, Cyprus, October 31 – November 5, 2016
Proceedings, Part I

Editors

Marinos Ioannides
Cyprus University of Technology
Limassol
Cyprus

Eleanor Fink
Arlington, VI
USA

Antonia Moropoulou
National Technical University of Athens
Athens
Greece

Monika Hagedorn-Saupe
Institut für Museumsforschung
Berlin
Germany

Antonella Fresa
Promoter s.r.l.
Peccioli
Italy

Gunnar Liestøl
University of Oslo
Oslo
Norway

Vlatka Rajcic
University of Zagreb
Zagreb
Croatia

Pierre Grussenmeyer
INSA
Strasbourg
France

Cover illustration: The illustration appearing on the cover of this book is used with permission.
Copyright holder: Byzantine Museum and Art Galleries, Archbishop Makarios III Foundation,
Arch. Kyprianos sqr., P.O. Box 21269, 1505 Nicosia, Cyprus. <http://www.makariosfoundation.org.cy>

ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-319-48495-2 ISBN 978-3-319-48496-9 (eBook)
DOI 10.1007/978-3-319-48496-9

Library of Congress Control Number: 2016956494

LNCS Sublibrary: SL3 – Information Systems and Applications, incl. Internet/Web, and HCI

© Springer International Publishing AG 2016

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Welcome to the proceedings of EuroMedMed 2016, the biennial scientific event which this year was held in the capital city of Cyprus, the island that 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 Skłodowska-Curie Fellowship project on Digital Heritage Marie Skłodowska-Curie FP7-PEOPLE ITN-DCH, the Marie Skłodowska-Curie FP7-IAPP 4D-CH-WORLD, the FP7-CIP ICT-PSP EuropeanaSpace, the H2020 Reflective 7 - INCEPTION, the H2020 CSA Virtual Museums ViMM, the Research Infrastructure DARIAH-EU ERIC and DARIAH-CY) as well as the Innovation in Intelligent Management of Heritage Buildings (i2MHB) decided to join EuroMed2016 and continue cooperating together in order to create an optimal environment for the discussion and explanation of new technologies, the 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.

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 6th European-Mediterranean Conference (EuroMed 2016) was definitely a forum for sharing views and experiences, discussing proposals for the optimum approach as well as the best practice and the ideal technical tools to preserve, document, manage, present/visualize and disseminate the rich and diverse cultural heritage of mankind.

This conference was held during the mid-term of the new Framework Programme, Horizon 2020, which is the largest in the world in terms of financial support on 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 current HORIZON 2020 that follows FP7 (2007–13). In the past 30 years, a large community of researchers, experts, and specialists have had the 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 programme and transferring knowledge to practice and supporting the development of SMEs.

The EuroMed 2016 agenda focused on enhancing 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 mobilizing also 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 changing the behavior of society. Joint European and international research produce 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 a challenge for our society. Close cooperation between professionals, policy makers, and authorities internationally is necessary for research, development, and technological advancements 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 on the never-ending journey in the 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.

In these proceedings we present 105 papers, selected from 504 submissions, which 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, Prof. Dr. Antonia Moropoulou (NTUA and Technical Chamber of Greece), Prof. Dr. Dieter Fellner (Director of FhD/IGD and TU Darmstadt, Germany), Prof. Dr. Wolfgang Kippes (University for Applied Arts Vienna and Donau University Krems, Austria), Prof. Dr. Sarah Whatley (Director of Centre for Dance Research, UK), Prof. Dr. Mustafa Erdik (Bogazici University of Instabul, Turkey), Mr. Jean-Pierre Massué (Senate Member of the European Academy of Sciences and Arts/COPRNM, France), Mr. Axel Ermert (Institute for Museum Research SMB/PK of Berlin, Germany), Mrs. Rosella Caffo (Director of the Central Institute for the Union

Catalogue of the Italian Libraries (ICCU), Italy), Mr. Vasco Fassina (President of the European Standardization Commission CEN/TC 346: Conservation of Cultural Heritage, Italy), Mrs. Maria P. Kouroupas (Director Cultural Heritage Center, US Department of State), Mrs. France Desmarais (ICOM), Dr. Thomas R. Klein (Counsel, Andrews Kurth LLP), Françoise Bortolotti (Criminal Intelligence Officer, Works of Art Unit, Interpol) and Prof. Dr. Markus Hilgert (Director, Vorderasiatisches Museum im Pergamonmuseum Staatliche Museen zu Berlin - Preußischer Kulturbesitz and Project Leader, ILLICID) 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 the EuroMed 2016 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 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. Kyriacos Themistocleous from the Cyprus Remote Sensing Society, who provided services and gifts in kind that made the conference possible.

We express our thanks and appreciation to Dr. Nikos Grammalides from CERTH in Greece and Dr. Sander Münster, the Dresden University of Technology, Germany, as well as the board of the ICOMOS Cyprus Section for their enthusiasm, commitment, and support for the success of this event. Most of all we would like to thank the organizations UNESCO, European Commission, CIPA, ISPRS, and ICOMOS Europa Nostra that entrusted us with the task of organizing and undertaking this unique event.

September 2016

Marinos Ioannides
Eleanor Fink
Antonia Moropoulou
Monika Hagedorn-Saupe
Antonella Fresca
Gunnar Liestøl
Vlatka Rajcic
Pierre Grussenmeyer

Acknowledgments and Disclaimer

The EuroMed 2016 conference was partly supported by the Republic of Cyprus, the Cyprus University of Technology, the Cyprus Tourism Organization, the CableNet Ltd., by CIPA (<http://cipa.icomos.org/>), ISPRS, ICOMOS, Europa Nostra the EU projects FP7 PEOPLE ITN2013 ITN-DCH and IAPP2012 4D-CH-WORLD, the DARIAH-EU ERIC and DARIAH-CY, the FP7-ICT-2011 i-Treasures, the CIP ICT-PSP EuropeanSpace and H2020 INCEPTION and H2020-ViMM projects.

However, the content of this publication reflects only the authors' views; the European Commission, the Republic of Cyprus, CIPA, ISPRS, ICOMOS, Europa Nostra, Cyprus University of Technology and the EU projects FP7 PEOPLE ITN2013 ITN-DCH and IAPP2012 4D-CH-WORLD, the DARIAH-EU ERIC and DARIAH-CY, the FP7-ICT-2011 i-Treasures, the CIP ICT-PSP EuropeanSpace and H2020-INCEPTION and H2020-ViMM are not liable for any use that may be made of the information contained herein.

Organization

Conference Chairs

Marinos Ioannides
Eleanor Fink
Antonia Moropoulou
Monika Hagedorn-Saupe
Antonella Fresa
Gunnar Liestøl
Vlatka Rajcic
Pierre Grussenmeyer

Paper Review Chair

Pavlos Chatzigrigoriou

Local Organizing Committee

Agapiou, Athos
Chatzigrigoriou, Pavlos
Eliades, Ioannis
Gkanetsos, Theodoros
Leventis, Georgios
Marina, Christodoulou
Nicolakopoulou, Vasiliki

Nobilakis, Elias
Papageorgiou, Eirini
Skriapas, Konstantinos
Yianni, Stephanie
Stylianou, Georgios
Themistocleous, Kyriacos
Athnasiou, Vasilios

International Scientific Committee

Agapiou, Athos	Cyprus	Caliandro, Rocco	Italy
Albertson, Lynda	Italy	Callet, Patrick	Italy
Angeletaki, Alexandra	Norway	Chatzigrigoriou, Pavlos	Greece
Balet, Olivier	France	Colla, Camilla	Italy
Barcelo, Juan	Spain	Corsi, Cristina	Italy
Bebis, George	USA	Cuca, Branca	Serbia
Belgiorno, Maria-Rosaria	Italy	Dallas, Costis	Canada
Bellini, Francesco	Italy	De Jong, Annemieke	Netherlands
Berni, Marco	Italy	De Kramer, Marleen	Austria
Bockholt, Ulrich	Germany	De Leeuw, Sonja	Netherlands
Bryan, Paul	UK	De Masi, Alessandro	Italy

De Niet, Marco	Netherlands	Liestøl, Gunnar	Norway
De Polo Saibanti, Andrea	Italy	Lobovikov Katz, Anna	Israel
Degraeve, Ann	Belgium	Lonnqvist, Minna	Lichtenstein
Dobрева, Milena	Malta	Lopez-Menchero Bendicho, Victor	Italy
Domajnko, Matevz	Slovenia		
Doneus, Michael	Austria	Madija, Lidija	Serbia
Doulamis, Anastasios	Greece	Maietti, Federica	Italy
Doulamis, Nikolaos	Greece	Makantasis, Konstantinos	Greece
Drap, Pierre	France	Marcella, Stefano	Italy
Eppich, Rand	USA	Martins, Joao	Portugal
Farrag, Maged	Egypt	Masini, Nicola	Italy
Filin, Sagi	Israel	Mate, Toth	Hungary
Fouseki, Kalliopi	UK	Michail, Harris	Cyprus
Fresa, Antonella	Italy	Moropoulou, Antonia	Greece
Frick, Jürgen	Germany	Munster, Sander	Germany
Gebhardt, Andreas	Germany	Nanetti, Andrea	Singapore
Giannouloupoulos, Giannoulis Georgios	Spain	Nikolakopoulou, Vasiliki	Greece
Giuliano, Angele	Italy	Nurminen, Antti	Finland
Graf, Holger	Germany	Nys, Karin	Belgium
Grammalidis, Nikos	Greece	Ouimet, Christian	Canada
Grosset, Marie	France	Papageorgiou, Dimitris	Greece
Grussenmeyer, Pierre	France	Papageorgiou, Eirini	Greece
Gutierrez, Mariano Flores	Spain	Papagiannakis, George	Greece
Gutiérrez Meana, Javier	Spain	Petrelli, Daniela	UK
Hagedorn-Saupe, Monika	Germany	Pietro, Liuzzo	Germany
Hanke, Klaus	Austria	Potsiou, Chryssy	Greece
Ibáñez, Francisco	Spain	Protopapadakis, Eftychios	Greece
Ioannidis, Charalambos	Greece	Radoslav, Pavlov	Bulgary
Jabi, Wassim	UK	Rajcic, Vlatka	Hungary
Kersten, Thomas	Germany	Rodriguez-Echavarria, Karina	UK
Klein, Michael	Austria		
Klein, Reinhard	Germany	Roko, Zarnic	Slovenia
Kolias, Stefanos	Greece	Ronchi, Alfredo	Italy
Koukios, Emmanuel	Greece	Saleh, Fathi	Egypt
Koutsabasis, Panayiotis	Greece	Sánchez Andreu, Joan	Spain
Kuroczyński, Piotr	Germany	Santana, Mario	Canada
Kyriakaki, Georgia	Greece	Santos, Pedro	Germany
Landes, Tania	France	Schindler, Mathias	Germany
Lange, Guus	Belgium	Sempere, Isabel Martínez	Spain
Laquidara, Giuseppe	Italy	Shang, Jin	China
Leissner, Johanna	Germany	Snyders, Marius	Netherlands
León, Alfredo Grande	Spain	Stork, Andre	Germany
Lerma, José Luis	Spain	Tapinaki, Sevasti	Greece
Leventis, Georgios	Greece	Themistocleous, Kyriacos	Cyprus
Liarokapis, Fotis	Greece	Thwaites, Harold	MY
		Tsai, Fuan	Taiwan

Tsapatsoulis, Nicolas	Cyprus	Vermeulen, Frank	Belgium
Tsiafaki, Despoina	Greece	Vosinakis, Spyros	Greece
Tsoupiakova, Daria	USA	Walczak, Krzysztof	Poland
Uueni, Andres	Estonia	Wallace, Manolis	Greece
Vander Vorst, Daniel	Spain	Wehr, Aloysius	Germany
Vassilara, Archontoula	Greece	Wilk, Christian	Germany
Vavalis, Manolis	Greece	Yen, Alex	Taiwan

The Icons of the Chapel of Saint Jacob

The icon shown on the cover of LNCS 10058 (Part I) depicts the scene of the Enthroned Virgin Mary with Child together with Saint John the Evangelist, while the icon shown on the cover of LNCS 10059 (Part II) illustrates Jesus Christ on a throne together with Saint John the Baptist. The icons are dated back to 1620 A.D. and were painted by the artist Meletios from Crete. These icons were stolen from the iconostasis of the chapel of Saint Jacob in Trikomo (Famagusta district) after the Turkish invasion of 1974. Saint Jacob's chapel had no frescoes but it was decorated with colorful plates of traditional folk art.

The icon illustrating Jesus Christ and Saint John the Baptist is 110 × 128 cm in size and close to the feet of the latter there is the inscription “ΧΕΙΡ ΜΕΛΕΤΙΟΥ ΤΟΥ ΚΡΙΤΟΣ ΑΧΚ(= 1620) Χ(ριστο) Υ. Μ(ηνοζ) αυγούστου),” which includes the name of the artist as well as the date. The icon of Mary, Mother of Jesus, together with Saint John the Evangelist is 114 × 134 cm in size. Both of them were in the possession of the Russian–Jewish art dealer Alexander Kocinski, until their confiscation by the Swiss Police in Zurich in 2007. The only documentation available to recover these stolen icons from abroad was a paper published in the *Proceedings of the International Cretan Conference* in 1976 by the former director of the Department of Antiquities of Cyprus, Mr. Athanasios Papageorgiou.

The icons were tracked down in 2007 in Christie's Auction House in London, from where they were withdrawn after actions by Kykkos Monastery. Following information by the bishop of Kykkos Monastery, representatives of the monastery traveled to Zurich to meet the owner of the icons; however, it was not possible to persuade him to return the icons to the lawful owners and therefore the authorities of Cyprus were informed. A written complaint by the Byzantinologist of Kykkos Monastery, Dr. C. Chotzakoglou, to the Cypriot Police and to Interpol in Cyprus initiated the repatriation procedure of the icons, eventually leading to their confiscation by the Swiss Interpol.

By means of a new testimony from Dr. C. Chotzakoglou, in addition to a full documentation of the Cypriot origin of the icons and their looting after the Turkish invasion in northern Cyprus, the Supreme Court of Famagusta, based in Larnaca, took legal measures against the owner of the icons, who was convicted. The verdict of the Cypriot Supreme Court was subsequently used in the Swiss Court, leading to the signing of a compromise settlement between the Church of Cyprus and Kocinski for the return of the icons to Cyprus.

Dr. Ioannis A. Eliades,
Director,
Byzantine Museum and Art Galleries,
Archbishop Makarios III Foundation,
Arch. Kyprianos sqr., P.O. Box 21269,
CY-1505 Nicosia, CYPRUS

Contents – Part I

Full Paper: 3D Reconstruction and 3D Modelling

Implementation and Usage Scenarios of a Participatory Platform for Cultural Environments	3
<i>Zois Koukopoulos and Dimitrios Koukopoulos</i>	
Benchmarking Close-range Structure from Motion 3D Reconstruction Software Under Varying Capturing Conditions	15
<i>Ivan Nikolov and Claus Madsen</i>	
Proportional Systems in the Design of the Cathedral of St. George of the Greeks, Cyprus	27
<i>Douglas Cawthorne and Romylos Irodotou</i>	
The Reconstruction – Argumentation Method: Proposal for a Minimum Standard of Documentation in the Context of Virtual Reconstructions	39
<i>Mieke Pfarr-Harfst and Marc Grellert</i>	
Multi-scale 3D Modelling of Damaged Cultural Sites: Use Cases and Image-Based Workflows	50
<i>Styliani Verykokou, Anastasios Doulamis, George Athanasiou, Charalabos Ioannidis, and Angelos Amditis</i>	
Low Cost Technique for Accurate Geometric Documentation of Complex Monuments by Non-experts	63
<i>Charalabos Ioannidis, Sofia Soile, and Styliani Verykokou</i>	

Full Paper: Heritage Building Information Models (HBIM)

Implementation of Scan-to-BIM and FEM for the Documentation and Analysis of Heritage Timber Roof Structures	79
<i>Maarten Bassier, George Hadjidemetriou, Maarten Vergauwen, Nathalie Van Roy, and Els Verstrynge</i>	
Implementation Analysis and Design for Energy Efficient Intervention on Heritage Buildings	91
<i>Elena Gigliarelli, Filippo Calcerano, and Luciano Cessari</i>	
Historic BIM in the Cloud	104
<i>Luigi Barazzetti, Fabrizio Banfi, and Raffaella Brumana</i>	

Building Information Modelling – A Novel Parametric Modeling Approach
Based on 3D Surveys of Historic Architecture 116
Fabrizio Banfi

Full Paper: Innovative Methods on Risk Assessment, Monitoring and Protection of Cultural Heritage

Applicability of 3DVE Indicator for Cultural Heritage Landscape Management. 131
Jaeyong Lee and Youngmo Kim

Taking the Next Step in Digital Documentation of Historic Cities: How HERMeS Evolved in an Open Data Digital Library of Historic Buildings 144
Pavlos Chatzigrigoriou

Risk Analysis and Vulnerability Assessment of Archeological Areas for the Preventive Conservation 157
Giuliana Quattrone

Full Paper: Intangible Cultural Heritage Documentation

Parameterizing the Geometry and Visualizing the Lighting Method of Byzantine Church Domes. 171
Wassim Jabi and Iakovos Potamianos

Digital and Handcrafting Processes Applied to Sound-Studies of Archaeological Bone Flutes 184
Etienne Safa, Jean-Baptiste Barreau, Ronan Gaugne, Wandrille Duchemin, Jean-Daniel Talma, Bruno Arnaldi, Georges Dumont, and Valérie Gouranton

Full Paper: Digital Applications for Materials’ Preservation and Conservation in Cultural Heritage

Evolution of Building Materials and Philosophy in Construction: A Process of Digitalization and Visualization of the Accumulated Knowledge 199
Ioanna Papayianni and Vasiliki Pachta

A Study of 3D Digital Simulation Analysis of Fire Charring Degree of Wood Construction of Chinese Traditional Architecture 209
Tsung Chiang Wu

Full Paper: Non-destructive Techniques in Cultural Heritage Conservation

Recovering Historical Film Footage by Processing
Microtomographic Images 219
*Chang Liu, Paul L. Rosin, Yu-Kun Lai, Graham R. Davis, David Mills,
and Charles Norton*

Multi-spectral Imaging System (IWN) for the Digitization and Investigation
of Cultural Heritage. 232
Ibrahim El-Rifai, Hend Mahgoub, and Ari Ide-Ektessabi

Diagnostic Activities for the Planned and Preventive Conservation
of Mosaic Pavements: The Case Study of the Triclinium
of the Villa Romana del Casale (Sicily) 241
Antonella Versaci, Alessio Cardaci, and Luca R. Fauzia

Full Paper: Visualisation, VR and AR Methods and Applications

A Mobile, AR Inside-Out Positional Tracking Algorithm, (MARIOPOT),
Suitable for Modern, Affordable Cardboard-Style VR HMDs 257
*Paul Zikas, Vasileios Bachlitzanakis, Margarita Papaefthymiou,
and George Papagiannakis*

Virtual and Augmented Reality Tools to Improve the Exploitation
of Underwater Archaeological Sites by Diver and Non-diver Tourists 269
*Fabio Bruno, Antonio Lagudi, Loris Barbieri, Maurizio Muzzupappa,
Gerardo Ritacco, Alessandro Cozza, Marco Cozza, Raffaele Peluso,
Marco Lupia, and Gianni Cario*

Interacting with Simulated Archaeological Assets 281
*Arian Goren, Kay Kohlmeyer, Thomas Bremer, Susanne Brandhorst,
Arie Kai-Browne, Felix Balda, David Strippgen, and Sebastian Plesch*

Virtual Reconstruction 3.0: New Approach of Web-based Visualisation
and Documentation of Lost Cultural Heritage 292
Daniel Dworak and Piotr Kuroczyński

**Full Paper: The New Era of Museums and Exhibitions: Digital Engagement
and Dissemination**

CultureCam: An Interactive Search Tool for Small Image Galleries 309
Sergiu Gordea, Michela Vignoli, and Sanna Marttila

Learning Algorithms for Digital Reconstruction of Van Gogh’s Drawings . . . 322
Yuan Zeng, Jiexiong Tang, Jan C.A. van der Lubbe, and Marco Loog

Full Paper: Digital Cultural Heritage in Education, Learning and Training

“Human” Technology in the Digital Era: Freehand Images and Analysis of Cultural Heritage – The Know-How and Its Applications	337
<i>Anna Lobovikov-Katz</i>	

Adult and Children User Experience with Leap Motion in Digital Heritage: The Cycladic Sculpture Application.	350
<i>Panayiotis Koutsabasis and Spyros Vosinakis</i>	

Researching Knowledge Concerns in Virtual Historical Architecture	362
<i>S. Münster, C. Kröber, H. Weller, and N. Prechtel</i>	

Project Paper: Data Acquisition, Process and Management in Cultural Heritage

Surveying Illusory Architectures Painted on Vaulted Surfaces.	377
<i>Matteo Flavio Mancini and Marta Salvatore</i>	

The Application of Photogrammetry on Digitization and Promotion for Monuments and Temples in Taiwan - Taking Chua Family Ancestral Temple as an Example	387
<i>Wun-Bin Yang, Tsung-Juang Wang, and Ya-Ning Yen</i>	

3D Acquisition, Processing and Visualization of Archaeological Artifacts: The Samarra Collection of the Museum of Islamic Art in Berlin	397
<i>Arie Kai-Browne, Kay Kohlmeyer, Julia Gonnella, Thomas Bremer, Susanne Brandhorst, Felix Balda, Sebastian Plesch, and Dennis Lehmann</i>	

PHOTOCONSORTIUM: Digitizing Europe’s Photographic Heritage	409
<i>Frederik Truyen and Antonella Fresca</i>	

Acquisition and Processing Experiences of Close Range UAV Images for the 3D Modeling of Heritage Buildings	420
<i>Arnadi Murtiyoso, Pierre Grussenmeyer, Mathieu Koehl, and Tristan Freville</i>	

Internal 3D Printing of Intricate Structures	432
<i>Théophane Nicolas, Ronan Gagne, Cédric Tavernier, Valérie Gouranton, and Bruno Arnaldi</i>	

Towards Monuments’ Holistic Digital Documentation: the Saint Neophytos Enkleistriotis Case Study	442
<i>Marinos Ioannides, Charalabos Ioannidis, Archimadrite Neophytos Enkleistriotis, David Castrillo, Pavlos Chatzigrigoriou, Eirini Papageorgiou, Georgios Leventis, Vasiliki Nikolakopoulou, Vasilis Athanasiou, Fotis Bourexis, Sofia Soile, Styliani Verykokou, Maria Costi de Castrillo, and Christian Sovis</i>	

Project Paper: Data, Metadata, Semantics and Ontologies in Cultural Heritage

First Experiences of Applying a Model Classification for Digital 3D Reconstruction in the Context of Humanities Research.	477
<i>Sander Münster, Cindy Kröber, Wolfgang Hegel, Mieke Pfarr-Harfst, Nikolas Prechtel, Rainer Uhlemann, and Frank Henze</i>	
Digital Preservation of Cultural Heritage: Balinese <i>Kulkul</i> Artefact and Practices	491
<i>Cokorda Pramatha and Joseph G. Davis</i>	
Interconnecting Objects, Visitors, Sites and (Hi)Stories Across Cultural and Historical Concepts: The CrossCult Project	501
<i>Costas Vassilakis, Angeliki Antoniou, George Lepouras, Manolis Wallace, Ioanna Lykourantzou, and Yannick Naudet</i>	

Project Paper: 3D Reconstruction and 3D Modelling

Debate and Considerations on Using Videos for Cultural Heritage from Social Media for 3D Modelling.	513
<i>Kyriacos Themistocleous</i>	
Investigations of Low-Cost Systems for 3D Reconstruction of Small Objects	521
<i>Thomas P. Kersten, Daniel Omelanowsky, and Maren Lindstaedt</i>	
Digital Documentation: Villa Borghese	533
<i>Martina Attenni, Cristiana Bartolomei, and Alfonso Ippolito</i>	
Digital 3D Reconstructed Models – Structuring Visualisation Project Workflows	544
<i>Mieke Pfarr-Harfst and Stefanie Wefers</i>	
Reconstruction of Wooden “Polish Manor”	556
<i>Anna Rozanska and Wojciech Koryciński</i>	

Project Paper: Heritage Building Information Models (HBIM)

Digital Tools for Heritage Preservation and Enhancement: The Integration of Processes and Technologies on 20th Century Buildings in Brazil and India	567
<i>Luca Rossato</i>	
From Integrated Survey to the Parametric Modeling of Degradations. A Feasible Workflow	579
<i>Massimiliano Lo Turco, Federico Caputo, and Gabriele Fusaro</i>	

INCEPTION Standard for Heritage BIM Models. 590
*Peter Bonsma, Iveta Bonsma, Anna Elisabetta Ziri, Silvia Parenti,
 Pedro Martín Lerones, José Luis Hernández, Federica Maietti,
 Marco Medici, Beatrice Turillazzi, and Ernesto Iadanza*

From SfM to Semantic-Aware BIM Objects of Architectural Elements 600
Massimiliano Lo Turco and Cettina Santagati

Project Paper: Novel Approaches to Landscapes in Cultural Heritage

Observing Landscape Changes Around the Nicosia Old Town Center
 Using Multi-temporal Datasets 615
Branka Cuca, Athos Agapiou, and Diofantos G. Hadjimitsis

Towards the Sustainable Development of Cultural Landscapes
 Through Two Case Studies on Different Scale 625
Eirini Papageorgiou

The Fortification System of the City of Urbino: The Case Study of Valbona
 Gate from 3D Surveys to GIS Applications for Dynamic Maps. 645
Sara Bertozzi, Laura Baratin, and Elvio Moretti

**Project Paper: Innovative Methods on Risk Assessment, Monitoring
 and Protection of Cultural Heritage**

Disaster-Risk Indicators and Their Evaluation, Communication
 for Traditional Settlement. 659
Alex Ya-Ning Yen and Chin-Fang Cheng

Pervasive Wireless Sensor Networks for the Monitoring of Large
 Monumental Structures: The Case of the Ancient City Walls of Siena 669
*Alessandro Pozzebon, Tommaso Addabbo, Ada Fort, Marco Mugnaini,
 Enza Panzardi, and Valerio Vignoli*

**Project Paper: Digital Applications for Materials’ Preservation
 and Conservation in Cultural Heritage**

The SACRE Project: A Diagnosis Tool of Built Heritage. 681
*Sarah Janvier-Badosa, Kévin Beck, Xavier Brunetaud,
 and Muzahim Al-Mukhtar*

Pigments Identification Using Raman Spectroscopy of the 16th Century
 Printed Book “Osorio”. 691
Igor Lukačević, Theodore Ganetsos, and Thomas Katsaros

Design and Application of a Data System for the Comparative Study
of Historic Mortars 701
Vasiliki Pachta and Ioanna Papayianni

GIS Applications for a New Approach to the Analysis of Panel Paintings . . . 711
Laura Baratin, Sara Bertozzi, Elvio Moretti, and Roberto Saccuman

Project Paper: Visualisation, VR and AR Methods and Applications

‘Translation’ and Fruition of an Ancient Book Through Virtual Reality
in the Case of Lost Cultural Heritage: Case Study: “*Inscriptiones*”
by Emmanuel Thesaurus 727
Sanaz Davardoust, Anna Osello, and Rosa Tamborrino

An Interdisciplinary Study on the Ancient Egyptian Wines:
The Egywine Project 737
Maria Rosa Guasch-Jané

ArchaeoInside: Multimodal Visualization of Augmented Reality
and Interaction with Archaeological Artifacts 749
Kadar Manuella and Domsa Ovidiu

DICE: Digital Immersive Cultural Environment 758
*Stelios C.A. Thomopoulos, Adam Doulgerakis, Maria Bessa,
Konstantinos Dimitros, Giorgos Farazis, Eftichia Georgiou,
Tassos Kanellos, Christina Karafylli, Maria Karafylli,
Dimitris M. Kyriazanos, Vassilios I. Kountouriotis,
Vassilis Lampropoulos, Christos Margonis, Christos Maroglou,
Dionisis Motos, Alexandra Papagianni, Manolis Paterakis,
Katerina Skroumpelou, Giorgos Konstandinos Thanos,
Ino-Eleni Theodorou, Christina Phobe Thomopoulos,
Panagiotis Tsimpiridis, Dimitris Zacharakis, and Andreas Zalonis*

**Project Paper: The New Era of Museums and Exhibitions: Digital
Engagement and Dissemination**

Imaging Novecento. A Mobile App for Automatic Recognition of Artworks
and Transfer of Artistic Styles 781
*Federico Becattini, Andrea Ferracani, Lea Landucci, Daniele Pezzatini,
Tiberio Uricchio, and Alberto Del Bimbo*

Towards the Design of a User-Friendly and Trustworthy Mobile System
for Museums 792
Kostas Koukoulis and Dimitrios Koukopoulos

Project Paper: Serious Games for Cultural Heritage

Project iMARECULTURE: Advanced VR, iMmersive Serious Games and Augmented Reality as Tools to Raise Awareness and Access to European Underwater CULTURAl heritagE.	805
<i>D. Skarlatos, P. Agrafiotis, T. Balogh, F. Bruno, F. Castro, B. Davide Petriaggi, S. Demesticha, A. Doulamis, P. Drap, A. Georgopoulos, F. Kikillos, P. Kyriakidis, F. Liarokapis, C. Poullis, and S. Rizvic</i>	
Immersivity and Playability Evaluation of a Game Experience in Cultural Heritage.	814
<i>Roberto Andreoli, Angela Corolla, Armando Faggiano, Delfina Malandrino, Donato Pirozzi, Mirta Ranaldi, Gianluca Santangelo, and Vittorio Scarano</i>	
Tirolcraft: The Quest of Children to Playing the Role of Planners at a Heritage Protected Town	825
<i>Bruno Amaral de Andrade, Ítalo Sousa de Sena, and Ana Clara Mourão Moura</i>	
Pervasive Game Utilizing WiFi Fingerprinting-based Localization	836
<i>Filip Maly, Pavel Kriz, and Michael Adamec</i>	

Project Paper: Digital Cultural Heritage in Education, Learning and Training

ErfgoedApp: An Educational Experiment with Augmented Reality, Cityscapes and Campusscapes in Brussels	849
<i>Marc Jacobs, Morien Schroyen, and Joke Vanderschoot</i>	
Contextualizing 3D Cultural Heritage	859
<i>James Lloyd</i>	
Crowdsourcing Cultural Heritage: From 3D Modeling to the Engagement of Young Generations	869
<i>Laura Inzerillo and Cettina Santagati</i>	
Training Schools for Conservation of Cultural Heritage: Between Expertise, Management and Education	880
<i>Anna Lobovikov-Katz, Gumersindo Bueno Benito, Vanesa Marcos Sánchez, Joao Martins, and Dalik Sojref</i>	
Educational Creative Use and Reuse of Digital Cultural Heritage Data for Cypriot UNESCO Monuments.	891
<i>Marinos Ioannides, Pavlos Chatzigrigoriou, Vasilis Bokolas, Vasiliki Nikolakopoulou, Vasilis Athanasiou, Eirini Papageorgiou, Georgios Leventis, and Christian Sovis</i>	

Time-Travelling with Mobile Augmented Reality: A Case Study
on the Piazza dei Miracoli 902
*Mihai Duguleana, Raffaello Brodi, Florin Gîrbacia, Cristian Postelnicu,
Octavian Machidon, and Marcello Carrozzino*

Author Index 913

INCEPTION Standard for Heritage BIM Models

Peter Bonsma^{1(✉)}, Iveta Bonsma¹, Anna Elisabetta Ziri², Silvia Parenti^{2(✉)},
Pedro Martín Lerones³, José Luis Hernández³, Federica Maietti⁴, Marco Medici⁴,
Beatrice Turillazzi⁵, and Ernesto Iadanza⁵

¹ RDF Ltd., Iskar 25, 1000 Sofia, Bulgaria

{peter.bonsma, iveta.bonsma}@rdf.bg

² Nemoris srl, Via Decumana 74 A, 40133 Bologna, Italy

{annaelisabetta.ziri, silvia.parenti}@nemoris.it

³ Fundación CARTIF, Parque Tecnológico de Boecillo, P. 205,

47151 Boecillo, Valladolid, Spain

{pedler, joshier}@cartif.es

⁴ Department of Architecture, University of Ferrara,

Via Ghiara 36, 44121 Ferrara, Italy

{federica.maietti, marco.medici}@unife.it

⁵ Consorzio Futuro in Ricerca,

Via Saragat 1, 44122 Ferrara, Italy

beatrice.turillazzi@unife.it, ernesto.iadanza@unifi.it

Abstract. The EU Project INCEPTION will create a platform that is able to exchange content according to state-of-the-art available open BIM standards. This INCEPTION open Heritage BIM platform is not only exchanging data according to existing state-of-the-art standards, but it is based on a new Heritage BIM model using Semantic Web technology. This allows applications to retrieve content according to modern query languages like SPARQL and allows user defined ‘on-the-fly’ extensions of the standard. This paper describes the structure and development of this new Heritage BIM standard. The Heritage BIM standard is developed by several Semantic Web and BIM standardization specialists in combination with top experts in the field of Cultural Heritage, all of them partners within the INCEPTION project.

Keywords: 3D · BIM · IFC · ifcOWL · GIS · H57 · H-BIM · OWL · OWL2 · Semantic web · RDF · RDFS

1 Introduction

The European Project “INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling”¹, funded by EC within the Programme Horizon 2020, focuses

¹ The INCEPTION project, Grand Agreement no.: 665220 started the last June 2015, is developed by a consortium of fourteen partners from ten European countries led by the Department of Architecture of the University of Ferrara. More information can be found on [<http://www.inception-project.eu/>].

on three main objectives: to create an inclusive understanding of European cultural identity and diversity by stimulating and facilitating collaborations across disciplines, technologies and sectors; to develop cost-effective procedures and enhancements for on-site 3D survey and reconstructions of cultural heritage buildings and sites; to develop an open-standard Semantic Web platform for accessing, processing and sharing interoperable digital models resulting from 3D survey and data capturing.

This inclusive approach includes open-standard format for cultural Heritage Building Information Modelling (H-BIM) as part of the overall procedure aimed at enriching and enhancing the changing role of 3D representations for knowledge, reconstruction, preservation and exploitation of Cultural Heritage.

The integration of semantic attributes with hierarchically and mutually aggregated 3D digital geometric models is essential for management of heritage information. The development of tools for 3D automatic delineation depending on acquisition technologies, from point clouds to photo-based data, allows to achieve a common standard interoperable output for BIM environment. Therefore, starting from advanced procedures aimed at handling multi-data point clouds and triangle meshes into BIM software, the INCEPTION procedure advances BIM approach for Heritage knowledge, going a step forward the usual procedure to locate/define 2D or 3D primitive shapes onto the point clouds. INCEPTION develops methodologies and algorithms to recognize these shapes. Results will be constructed in BIM software avoiding the oversimplification of the shapes. When used in models of Cultural Heritage, semantic BIM will be able to be connected to different users (e.g. scholars, technicians, citizens, etc.) in support of the user's needs for interpretation of the cultural heritage model, in addition to the common BIM features of 3D visualization, technical specifications and dataset.

The recent earthquake in central Italy (23 August 2016), causing about 300 victims, almost destroyed the beautiful towns of Accumoli and Amatrice. The last one was inserted in 2015 among the “most beautiful villages of Italy”. Both the towns date back to XI–XII centuries and are home to beautiful churches and sanctuaries, heavily damaged by the earthquake. The same fate has befallen many houses of historical interest. Similarly, in 2009, the same region was hit by a big earthquake that fatally wounded the wonderful ancient city of L'Aquila, still undergoing a slow process of architectural recovery, causing 309 victims.

One of the aims of the INCEPTION procedure is protecting the cultural heritage of seismic areas with scopes of classification, prevention and reconstruction.

The paper starts exploring the state of the art within existing open standards, focusing on available H-BIM solutions up to explaining INCEPTION implementations.

2 Existing Open Standards

In the area of BIM, GIS, Cultural Heritage and Semantic Web, a lot of valuable work is already done. INCEPTION has taken existing state-of-the-art open standards and technology as a starting point. In this chapter we will just name a few relevant open standards in the area of BIM and Point Clouds, without being complete in number of standards

nor in the areas (for example GIS was removed completely keeping the paper size reasonable). A complete reference can be found in D4.1 from the INCEPTION project.

2.1 Existing BIM Standards

This paragraph will explain the main open BIM standards expected to be used for data providers of BIM.

IFC (ifcXML, ifcOWL, ifczip). The first developments for the IFC format dates back to 1985. The name IFC (Industry Foundation Classes) was first introduced in 1994 led by Autodesk. In 1995 it became a vendor independent standard and had several releases, IFC 151 and IFC 20LF (Long Form) were popular releases for the academic world. Since IFC 2 × 3 released in 2006 (and later improvements IFC 2 × 3 Final and IFC 2 × 3 TC1) it was also becoming more popular for use in real life projects. Nowadays IFC 2 × 3 TC1 is still the most popular version although for INCEPTION the new version IFC4 (formally known as IFC 2 × 4) has some important improvements for both 3D representation and scheduling.

IFC is meant to be used by all the disciplines in the Building & Construction industry and the only widely used open standard supporting so many different disciplines. All major CAD vendors and a wide variety of other applications offer support for IFC. Most of the applications supporting IFC are not certified, although most CAD systems with IFC support have a certification from buildingSMART. IFC carries an object-based view of the model, including geometry in 3D (and 2D) as well as properties and interrelationships between objects. It is a well thought through standard with relatively high complexity for software vendors to support. IFC support includes schedule data, quantities and many other construction related data.

The standard exchange format for IFC is STEP/EXPRESS. As serialization support for this format is limited the past few years other serializations are defined also. It started with support for ifcXML, with an alternative ‘simple’ ifcXML format. More recently also ifcOWL serialization is created, this last format is compatible with Semantic Web RDF, RDFS and OWL2 standards. Although there is a small data loss the fast majority of knowledge is kept in these alternative serializations. A different format is ifczip and is nothing more than the zipped version of an original IFC file.

bsDD. Building Smart Data Dictionary is like the semantic extension of the IFC schema. Although IFC in combination with its property sets (and about 3000 properties) has already a lot of semantics in it, to cover the complete Building & Construction industry the semantic definition has to be far larger (numbers differ but we could expect that 100.000 object definitions are required where even the latest IFC schema has less than 1000 entities). bsDD is the standard from Building Smart defining how such extensions of the semantics can be stored and defined.

2.2 Existing Point-Cloud Standards

E57. Most 3D imaging systems for data exchange today takes place using one of three types of file formats: proprietary formats (not an efficient approach to data exchange in the long term), ad-hoc formats (not space or time efficient and no widespread usage), or the LAS format (limited file size and features). The E57 format is intended to overcome these issues, being a more general format that is well-suited for storing data across a variety of application domains. It is able to store point clouds and also other information from 3D scanners like images. The file format is specified by the ASTM, an international standards organization, and it is documented in the ASTM E2807 standard Huber (2011).

Next to the standard a ‘reference implementation’ is created to make more attractive and easy the use of the standard. The reference implementation is called libE57 and is written in C++ and sources are available [<http://www.libe57.org/>]. The libE57 application contains an API that can be used by parties that like to import or export files in E57 format.

2.3 Available H-BIM Solutions

Several H-BIM Solutions are already available. One thing we can notice in many of these solutions is use of Semantic Web techniques or use of BIM related standards. For example the vendor specific standard Graphisoft GDL language (Graphical Description Language) allows parametric modelling of components, something very useful in the area of geometry for Cultural Heritage content.

One typical behavior of most currently available H-BIM solutions is that they are clearly focused on one or two areas of the core of a Semantic Web based solution:

- Cultural Heritage
- Semantic Web technology
- BIM /3D /Point Cloud knowledge

3 Semantic Web

3.1 RDF

RDF (Resource Description Framework) supports creating and processing metadata by defining a default structure. This structure can be used for any data, independent of their character. Thus, the application areas of RDF are numerous, e.g., web-based services, peer-to-peer networks, and semantic caching models; they all have in common that huge amounts of data have to be processed when querying RDF data. RDF data can be represented using XML, a triple structure or a graph. Only the graph representation enables the semantic interpretation of the RDF schema.

All of the elements of the triple are resources with the exception of the last element, object, that can be also a literal. Literal, in the RDF sense, is a constant string value such as string or number. Literals can be either plain literals (without type) or typed literals

typed using XML Datatypes. These triples together form RDF graph. A normative syntax for serializing RDF is RDF/XML.

3.2 RDF Schema (RDFS)

RDFS extends RDF vocabulary to allow describing taxonomies of classes and properties. It also extends definitions for some of the elements of RDF; for example it sets the domain and range of properties and relates the RDF classes and properties into taxonomies using the RDFS vocabulary.

The RDF schema statements are valid RDF statements because their structure follows the structure of the RDF data model. The only difference to a pure “resource - property - value” - triple is that an agreement about the specific meaning for reserved terms and statements has been made. Next to that, the RDF schema provides a vocabulary for defining the semantics of RDF statements.

3.3 Web Ontology Language (OWL)

OWL is a W3C standard. The abbreviation stands for Web Ontology Language and is a language for processing information on the web. It is built on top of RDF and RDFS. OWL was designed to be interpreted by computers and parsed by applications. It is not meant for being read by people. OWL is written in XML and has three sublanguages - OWL Lite, OWL DL (includes OWL Lite) and OWL Full (includes OWL DL). The Ontology is about the exact description of things and their relationships. For the web, ontology is about the exact description of web information and relationships between web information. The standard OWL is a part of the “Semantic Web Vision”, a future web where:

- Web information has exact meaning
- Web information can be processed by computers
- Computers can integrate information from the web

3.4 Web Ontology Language 2 (OWL2)

OWL 2 adds new functionalities with respect to OWL 1. Some of the new features are syntactic sugar (e.g., disjoint union of classes) while others offer new expressivity, including keys, property chains, richer data types, data ranges, qualified cardinality restrictions, asymmetric, reflexive, and disjoint properties, and enhanced annotation capabilities. OWL 2 also defines three new profiles and a new syntax. Some of the restrictions applicable to OWL DL have been relaxed resulting in a slightly larger set of RDF Graphs that can be handled by Description Logics reasoners.

3.5 Reasoning

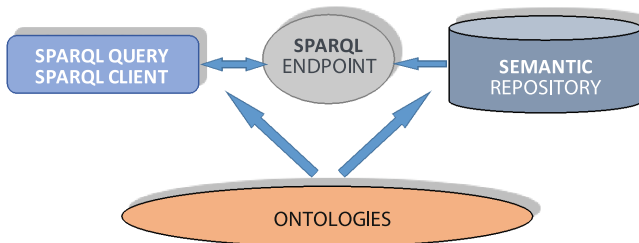
OWL enables “reasoning”, as mentioned above. That means it gives the possibility to check the logical correctness of statements and add statements that are implied by other statements

A “semantic reasoner”, “reasoning engine”, “rules engine”, or simply a “reasoner”, is a piece of software able to infer logical consequences from a set of asserted facts or axioms. The notion of semantic reasoner generalizes that concept of inference engine, by providing a richer set of mechanisms to work with. The inference rules are commonly specified by means of an ontology language, and often a description language. Many reasoners use first-order predicate logic to perform reasoning; inference commonly proceeds by forward chaining and backward chaining. There are also examples of probabilistic reasoners, including Pei Wang’s non-axiomatic reasoning system, and Nova-mente’s probabilistic logic network.

3.6 SPARQL

SPARQL is the reasoning language for Semantic Web. Servers support in many cases out-of-the-box SPARQL queries.

The gate for the access to the Inception ontology will be a SPARQL endpoint. SPARQL 1.1 is a semantic query language and a recommendation of W3C. Its adoption in Inception project is important to access to the CH semantic storage. Multiple programming languages, libraries and semantic repositories implement SPARQL queries. The 1.1 standard also allows to write queries which directly update the RDF graph. Being SPARQL syntax based on graph traversal, it is also easy to visualize SPARQL results graphically. Although repositories could be navigated and examined with different tools, a SPARQL endpoint is one of the powerful tools to open semantic data to main exploitation.



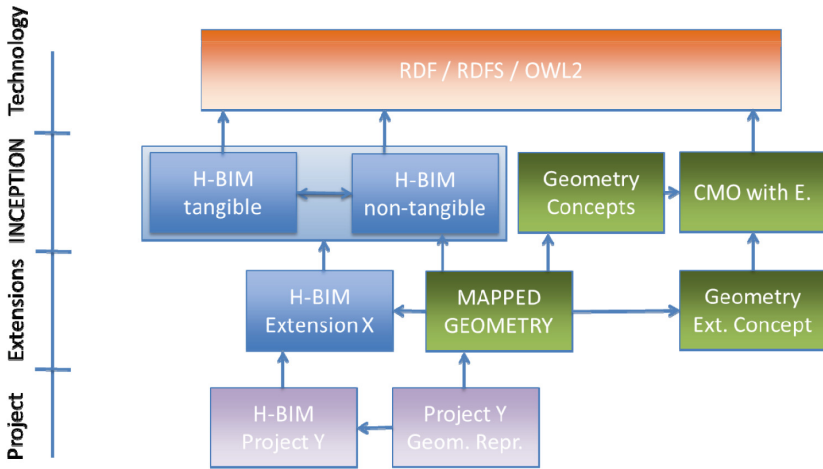
4 H-BIM Ontology

This chapter describes the architecture of the H-BIM Ontology as well as some examples of the content. The H-BIM Ontology is the core of the INCEPTION Platform. The content of the Ontology will be developed together with the specialists that are partners within INCEPTION. By definition the content will however be incomplete; the architecture therefore allows users to extend the H-BIM Ontology either for projects or for larger aggregations, like countries, styles etc.

4.1 Background

The architecture of the H-BIM Ontology is defined to enable storage of semantic information from any cultural heritage object. A clear distinction between tangible and non-tangible content is defined and, in line with the base concepts behind Semantic Web technology, it allows layered extension of the ontology itself. Typical for the H-BIM Ontology is the close connection with existing state-of-the-art BIM standards like IFC/ ifcOWL and the link with 3D content defined in Semantic Web (i.e. open standard CMO with Extensions).

4.2 Architecture Overview



4.3 Technology Layer

Within this layer we use the Semantic Web technology as described in Sect. 3. This means use of the RDF, RDFS and OWL2 as top layers of the H-BIM Ontology.

4.4 INCEPTION Layer

The INCEPTION layer of the H-BIM model contains the real knowledge from the specialists within the INCEPTION project. This is knowledge about Cultural Heritage but also knowledge from existing state-of-the-art open BIM and open GIS standards.

One important part of the INCEPTION layer is the difference between tangible and non-tangible results. Since this is a known term in the area of Cultural Heritage and distinction is not always clear, much time and effort is put in defining what is covered by the terms.

4.5 Extensions Layer

As soon as new concepts within the extension layer are defined the queries can be used. Extension could concern new relations between existing content and therefore applied on all existing content, but extensions can also be specific for dedicated content. Some examples:

Example of Extensions Applicable on Existing Content. The INCEPTION H-BIM standard has embedded parts of the semantic structure of IFC (and therefore ifcOWL). This means classes `Wall`, `WallStandardCase` and `Cur-tainWall` exist. Adding a super class `Walls` and the knowledge that above named classes inherit from this new class `Wall` is an extension that works on all available content. A SPARQL query can be created to get all instances of new class `Walls` and it will directly have content for the majority of the Cultural Heritage H-BIM models stored in the INCEPTION platform.

Example of Extensions Applicable on New Content. It is allowed to add a class to the H-BIM model in the extension layer with a new name and no relation to any existing part of the H-BIM model. A query on this class is only relevant for new content incorporating the knowledge that this new class is existing.

4.6 Project Layer

Within the project layer the real content is defined, this content is arranged according to the layers above. All content can be queried according to the SPARQL queries defined on top of the INCEPTION layer. It is also possible to create solution specific queries as well as queries dedicated to certain extensions as defined in the extension layer.

5 Implementation

The INCEPTION standard is the base for the platform that will be developed within INCEPTION. As the INCEPTION standard is developed.

5.1 Server Solutions

The core of the INCEPTION platform will be a server that is able to handle the INCEPTION standard and offer basic functionality like support for SPARQL. During writing of this paper the selection of the server handling this Semantic Web data is not finalized yet, there are several options and the most promising solutions at this moment seem to be RDF4 J and Fuseki 2.

As not only Semantic Web data needs to be stored, but many different file formats including open standard BIM formats as well as point cloud data a file server will be part of the INCEPTION platform also.

Sesame /RDF4J 2.0. The official name is RDF4J and its current release is 2.0, however this solution is best known under its former name OpenRDF Sesame framework. It

became part of the Eclipse Foundation and has no official first version at this moment after this important change.

Fuseki 2. Fuseki server is already existing for a while and although especially Fuseki 2 would be of interest for INCEPTION also Fuseki 1 is still actively maintained. Fuseki 2 is a server solution on top of Apache and Jena and also called Apache Jena Fuseki. It is a SPARQL server and an open source project.

5.2 SPARQL Queries

Technology choices and implementation will be driven by the accessibility of data through SPARQL queries addressed to a SPARQL endpoint. This means that a running REST web service should respond to data queries and produce as results a set of triples serialized on one of the most used RDF serialization (RDF/XML, Turtle, N3) or an RDF graph. This should include queries both on tangible and non-tangible data and their specific relations.

SPARQL queries are “data-oriented” so there is no inference in the query language itself, all the data manipulation and inferencing has to be done by a layer on storage or on in memory RDF data. Thanks to its structure and many converters present in the market SPARQL queries can be applied not only to native RDF data but also on any data that could be mapped to RDF, like other kind of well-formed relational data.

6 Conclusion

The use of BIM for Cultural Heritage is becoming more and more an effective tool to manage 3D representations at different layers and for multiple purposes, pursuing the common vision, at European level, to apply research, technology and innovation in innovative media to expand understanding and access of the heritage assets.

One of the main challenges is how to manage the complexity of heritage buildings and sites, fostering the collaboration across disciplines through semantic-aware representations, able to solve interoperability issues and avoiding the segmentation of knowledge. The technology of Semantic Web and integration with 3D and BIM are the drivers behind H-BIM Ontology. The H-BIM Ontology in its turn is the core of the INCEPTION H-BIM Platform.

The INCEPTION procedure could be conveniently exploited for protecting the cultural heritage of seismic areas with scopes of classification, prevention and reconstruction.

References

- Bonsma, P.: Semantic web platform and interfaces. In: Deliverable 6.2 of the EU Project Proficient (2014)
- Huber, D.: The ASTM E57 file format for 3D imaging data exchange. In: Proceedings of the SPIE, Electronics Imaging Science and Technology Conference (IS&T), 3D Imaging Metrology, vol. 7864A, January 2011

- Dore, C., Murphy, M.: Integration of Historic Building Information Modeling (HBIM) and 3D GIS for recording and managing cultural heritage sites. In: 2012 18th International Conference on Virtual Systems and Multimedia (VSMM), pp. 369–376. IEEE (2012)
- Hichri, N., Stefani, C., De Luca, L.; Veron, P.; Hamon, G.: From point cloud to BIM: a survey of existing approaches. In: International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XL-5/W2 (2013)
- Volk, R., Stengel, J., Schultmann, F.: Building Information Modeling (BIM) for existing buildings - literature review and future needs. *Autom. Constr.* **38**, 109–127 (2014)
- Kauppinen, T., Paakkarinen, P., Mäkelä, E., Kuittinen, H., Väättäin, J., Hyvönen, E.: Geospatio-temporal Semantic Web for Cultural Heritage (2010)
- BauDenkMalNetz – Creating a Semantically Annotated Web Resource of Historical Buildings- Anca Dumitrache and Christoph Lange
- Mantegari, G., Palmonari, M., Vizzari, G.: Rapid prototyping a semantic web application for cultural heritage: the case of MANTIC. In: Aroyo, L., Antoniou, G., Hyvönen, E., Teije, A., Stuckenschmidt, H., Cabral, L., Tudorache, T. (eds.) ESWC 2010. LNCS, vol. 6089, pp. 406–410. Springer, Heidelberg (2010). doi:[10.1007/978-3-642-13489-0_33](https://doi.org/10.1007/978-3-642-13489-0_33)
- Pauwels, P., Verstraeten, R., De Meyer, R., Van Campenhout, J.: Architectural Information Modelling in Construction History (2009)

Author Index

- Aalil, Issam II-160
Adamec, Michael I-836
Addabbo, Tommaso I-669
Agapiou, Athos I-615, II-91, II-171, II-275
Agrafiotis, P. I-805
Al-Mukhtar, Muzahim I-681, II-53, II-160
Amditis, Angelos I-50
Anagnostoudis, Pavlos II-118
Andersson, John II-33
Andreoli, Roberto I-814
Antoniou, Angeliki I-501
Arnaldi, Bruno I-184, I-432
Athanasίου, George I-50
Athanasίου, Vasilis I-442, I-891, II-256, II-265
Atki, Mustapha II-160
Attenni, Martina I-533
Avouris, Nikolaos M. II-199
- Bachlitzanakis, Vasileios I-257
Badreddine, Dalal II-160
Balda, Felix I-281, I-397
Balogh, T. I-805
Banfi, Fabrizio I-104, I-116
Baratin, Laura I-645, I-711
Barazzetti, Luigi I-104
Barbieri, Loris I-269
Barreau, Jean-Baptiste I-184
Bartolomei, Cristiana I-533
Bassier, Maarten I-79
Becattini, Federico I-781
Beck, Kévin I-681, II-53, II-160
Bertozzi, Sara I-645, I-711
Bessa, Maria I-758
Biliotti, Francesca II-232
Biscione, Marilisa II-99, II-275
Bokolas, Vassilis I-891, II-118
Bonsma, Iveta I-590
Bonsma, Peter I-590
Bourexis, Fotis I-442
Brandhorst, Susanne I-281, I-397
Brcic, Ramon II-275
Bremer, Thomas I-281, I-397
Brodi, Raffaello I-902
- Brumana, Raffaella I-104
Brunetaud, Xavier I-681, II-53, II-160
Bruno, Fabio I-269, I-805
Bueno Benito, Gumersindo I-880
Bugadze, Nino II-16
- Calamai, Silvia II-232
Calcerano, Filippo I-91
Caldeira, Altino Barbosa II-248
Caneva, Stefano G. II-222
Caputo, Federico I-579
Cardaci, Alessio I-241
Cario, Gianni I-269
Carrozzino, Marcello I-902
Casagrande, Pedro II-63
Castrillo, David I-442
Castro, F. I-805
Cawthorne, Douglas I-27
Cerra, Daniele II-275
Cessari, Luciano I-91
Chaaba, Ali II-160
Chatzigrigoriou, Pavlos I-144, I-442, I-891, II-256, II-265
Cheng, Chin-Fang I-659
Cherkaoui, Khalid II-160
Ciacci, Andrea II-130
Cigna, Francesca II-91
Clément, Serain II-283
Constantinou, Vaso II-214
Corolla, Angela I-814
Cozza, Alessandro I-269
Cozza, Marco I-269
Crosta, Giovanni II-91
Cuca, Branka I-615, II-91, II-275
- Danese, M. II-99
Davardoust, Sanaz I-727
Davis, Graham R. I-219
Davis, Joseph G. I-491
de Andrade, Bruno Amaral I-825
de Bouw, Michael II-141
de Castrillo, Maria Costi I-442
de Sena, Ítalo Sousa I-825
Dekeyser, Liesbeth II-141

- Del Bimbo, Alberto I-781
 Deleplancque, Remi II-160
 Demesticha, S. I-805
 Dimitros, Konstantinos I-758
 Dinu, M. II-151
 Doulamis, Anastasios I-50, I-805
 Doulgerakis, Adam I-758
 Drap, P. I-805
 Dubois, Samuel II-141
 Duchemin, Wandrille I-184
 Duguleana, Mihai I-902
 Dumont, Georges I-184
 Dworak, Daniel I-292
- Eineder, Michael II-275
 El-Rifai, Ibrahim I-232
 Enkleistriotis, Archimadrite Neophytos
 I-442
- Faggiano, Armando I-814
 Farazis, Giorgos I-758
 Fauzia, Luca R. I-241
 Ferracani, Andrea I-781
 Ferrari, Federico II-16
 Fidas, Christos A. II-199
 Fischer, H. II-151
 Fonseca, Bráulio II-63
 Fort, Ada I-669
 Fratini, Paolo II-91
 Fresa, Antonella I-409
 Freville, Tristan I-420
 Fusaro, Gabriele I-579
- Ganetsos, Theodore I-691
 Gaugne, Ronan I-184, I-432
 Georgiou, Eftichia I-758
 Georgopoulos, A. I-805
 Gessner, Ursula II-275
 Gliharelli, Elena I-91
 Girbacia, Florin I-902
 Gizzi, F.T. II-99
 Gómez-García-Bermejo, Jaime II-25
 Gonnella, Julia I-397
 Gordea, Sergiu I-309, II-109
 Goren, Arian I-281
 Gouranton, Valérie I-184, I-432
 Grellert, Marc I-39
 Grussenmeyer, Pierre I-420
 Guasch-Jané, Maria Rosa I-737
- Hadjidemetriou, George I-79
 Hadjimitsis, Diofantos G. I-615, II-91,
 II-171, II-275
 Hegel, Wolfgang I-477
 Henze, Frank I-477
 Hernández, José Luis I-590
- Iadanza, Ernesto I-590
 Ide-Ektessabi, Ari I-232
 Inzerillo, Laura I-869
 Ioannides, Marinos I-442, I-891, II-256,
 II-265
 Ioannidis, Charalabos I-50, I-63, I-442
 Ioannou, Andri II-214
 Ippolito, Alfonso I-533
 Irodoutou, Romylos I-27
 Ispas, A. II-151
- Jabi, Wassim I-171
 Jacobs, Marc I-849
 Janvier, Romain II-53, II-160
 Janvier-Badosa, Sarah I-681, II-53
- Kadar, Manuella I-749
 Kai-Browne, Arie I-281, I-397
 Kalle-den Oudsten, Inge II-209
 Kanellos, Tassos I-758
 Karafylli, Christina I-758
 Karafylli, Maria I-758
 Katsaros, Thomas I-691
 Kersten, Thomas P. I-521
 Kikillos, F. I-805
 Kim, Youngmo I-131
 Koehl, Mathieu I-420
 Kohlmeyer, Kay I-281, I-397
 Koryciński, Wojciech I-556
 Kouhartsouk, Demetris II-91
 Koukopoulos, Dimitrios I-3, I-792
 Koukopoulos, Zoia I-3
 Koukoulis, Kostas I-792
 Kountouriotis, Vassilios I. I-758
 Koutsabasis, Panayiotis I-350
 Kovačević, Sandra II-72
 Krauss, Thomas II-275
 Kriz, Pavel I-836
 Kröber, Cindy I-362, I-477
 Kubišta, Jiří II-191
 Kuprashvili, Nana II-16
 Kuroczyński, Piotr I-292

- Kyriakidis, P. I-805, II-91
 Kyriazanos, Dimitris M. I-758
- La Guardia, M. II-41
 Lagudi, Antonio I-269
 Lai, Yu-Kun I-219
 Lampropoulos, Vassilis I-758
 Landucci, Lea I-781
 Lanitis, Andreas II-240
 Larsson, Carolina II-10
 Lasaponara, Rosa II-275
 Lee, Jaeyong I-131
 Lee, Tung-Ming II-81
 Lehmann, Dennis I-397
 Lepouras, George I-501
 Leronas, Pedro Martín I-590, II-25
 Leventis, Georgios I-442, I-891, II-256,
 II-265
 Liarokapis, F. I-805
 Lindgren, Stefan II-10
 Lindstaedt, Maren I-521
 Liu, Chang I-219
 Llamas, Jose II-25
 Lloyd, James I-859
 Lo Turco, Massimiliano I-579, I-600
 Lobovikov-Katz, Anna I-337, I-880
 Loizides, Fernando II-214
 Loog, Marco I-322
 Lukačević, Igor I-691
 Lupia, Marco I-269
 Lykourantzou, Ioanna I-501
 Lysandrou, Vasiliki II-91, II-275
- Machidon, Octavian I-902
 Madsen, Claus I-15
 Mahgoub, Hend I-232
 Mahjoubi, Rachida II-160
 Maiellaro, Nicola II-178
 Maietti, Federica I-590
 Malandrino, Delfina I-814
 Maly, Filip I-836
 Mancini, Matteo Flavio I-377
 Marcos Sánchez, Vanesa I-880
 Margonis, Christos I-758
 Margottini, Claudio II-91
 Markiewicz, J. II-3
 Maroglou, Christos I-758
 Martins, Joao I-880
- Marttila, Sanna I-309
 Masini, Nicola II-99, II-275
 Medici, Marco I-590, II-16
 Meliva, Tamar II-16
 Merodo, José Antonio Fernandez II-91
 Mills, David I-219
 Moretti, Elvio I-645, I-711
 Motos, Dionisis I-758
 Motta, Silvio Romero Fonseca II-248
 Moura, Ana Clara Mourão I-825, II-63
 Mugnaini, Marco I-669
 Münster, Sander I-362, I-477
 Murtiyoso, Arnadi I-420
 Muzzupappa, Maurizio I-269
- Naudet, Yannick I-501
 Nicolas, Théophane I-432
 Nigdelis, Pantelis II-118
 Nikolakopoulou, Vasiliki I-442, I-891,
 II-256, II-265
 Nikolov, Ivan I-15
 Nisantzi, Argyro II-275
 Nolè, Gabriele II-275
 Norton, Charles I-219
- Omelanowsky, Daniel I-521
 Osello, Anna I-727
 Ovidiu, Domsa I-749
- Pachta, Vasiliki I-199, I-701
 Panayiotou, Stavros II-240
 Panzardi, Enza I-669
 Papaefthymiou, Margarita I-257
 Papageorgiou, Eirini I-442, I-625, I-891,
 II-256, II-265
 Papagiannakis, George I-257
 Papagianni, Alexandra I-758
 Papayianni, Ioanna I-199, I-701
 Parenti, Silvia I-590
 Paterakis, Manolis I-758
 Pecci, A. II-99
 Pelcer–Vujačić, Olga II-72
 Peluso, Raffaele I-269
 Petriaggi, B. Davidde I-805
 Pezzatini, Daniele I-781
 Pfarr-Harfst, Mieke I-39, I-477, I-544
 Pirozzi, Donato I-814
 Plesch, Sebastian I-281, I-397

- Popescu, C. II-151
 Postelnicu, Cristian I-902
 Potamianos, Iakovos I-171
 Potenza, M.R. II-99
 Poullis, C. I-805
 Pozzebon, Alessandro I-669, II-130, II-232
 Pramatha, Cokorda I-491
 Prechtel, Nikolas I-362, I-477
- Quattrone, Giuliana I-157
- Rădulescu, H.C. II-151
 Radvan, R. II-151
 Ranaldi, Mirta I-814
 Raptis, George E. II-199
 Ritacco, Gerardo I-269
 Rizvic, S. I-805
 Rocha, Nicole II-63
 Roedel, P. II-151
 Rosin, Paul L. I-219
 Rossato, Luca I-567
 Roşu, G. II-151
 Rozanska, Anna I-556
- Saccuman, Roberto I-711
 Safa, Etienne I-184
 Sakali, Ayda II-160
 Salvatore, Marta I-377
 Santagati, Cettina I-600, I-869
 Santangelo, Gianluca I-814
 Scaduto, M.L. II-41
 Scarano, Vittorio I-814
 Scavone, M. II-99
 Schindler, Alexander II-109
 Schreier, Gunter II-275
 Schroyen, Morien I-849
 Scianna, A. II-41
 Sena, Ítalo II-63
 Sileo, M. II-99
 Skarlatos, D. I-805
 Skroumpelou, Katerina I-758
 Soile, Sofia I-63, I-442
 Sojref, Dalik I-880
 Sovis, Christian I-442, I-891, II-256, II-265
 Spizzichino, Daniele II-91
 Strand, Eva Andersson II-10
 Strippen, David I-281
- Talma, Jean-Daniel I-184
 Tamborrino, Rosa I-727
 Tang, Jiexiong I-322
 Tavernier, Cédric I-432
 Thanos, Giorgos Konstandinos I-758
 Themistocleous, Kyriacos I-513, II-91, II-171, II-275
 Theodorou, Ino-Eleni I-758
 Thomopoulos, Christina Phobe I-758
 Thomopoulos, Stelios C.A. I-758
 Truyen, Frederik I-409
 Tsimpiridis, Panagiotis I-758
 Turillazzi, Beatrice I-590
 Tzouvaras, Marios II-91
- Ubik, Sven II-191
 Uhlemann, Rainer I-477
 Uricchio, Tiberio I-781
- van Biessum, Harry II-109
 Van Damme, Peter II-141
 Van der Have, Joeri-Aleksander II-141
 van der Lubbe, Jan C.A. I-322
 van Oppen, Branko F. II-222
 Van Roy, Nathalie I-79
 Vanderschoot, Joke I-849
 Vanhellemont, Yves II-141
 Varasano, Antonietta II-178
 Vassilakis, Costas I-501
 Vergauwen, Maarten I-79
 Vermeir, Simon II-141
 Versaci, Antonella I-241
 Verstrynge, Els I-79
 Verykokou, Styliani I-50, I-63, I-442
 Vignoli, Michela I-309
 Vignoli, Valerio I-669
 Vosinakis, Spyros I-350
 Vouronikou, Nikoleta II-118
- Wallace, Manolis I-501
 Wang, Tsung-Juang I-387
 Wefers, Stefanie I-544
 Weller, H. I-362
 Wu, Tsung Chiang I-209
- Yang, Wun-Bin I-387
 Yen, Alex Ya-Ning I-659, II-81
 Yen, Ya-Ning I-387

Zacharakis, Dimitris [I-758](#)
Zalama, Eduardo [II-25](#)
Zalonis, Andreas [I-758](#)
Zawieska, D. [II-3](#)

Zeng, Yuan [I-322](#)
Zikas, Paul [I-257](#)
Ziri, Anna Elisabetta [I-590](#)