CONFERENCE PROCEEDINGS

2025 IMEKO TC26 INTERNATIONAL CONFERENCE ON

METROLOGY for ARCHAEOLOGY and CULTURAL HERITAGE

BERGAMO, ITALY OCTOBER 15-17, 2025

METRO ARCHAEO

BERGAMO 2025

CONFERENCE PROGRAM

Wednesday, October 15

Session 1.1 - Geomatics for Archaeology and Cultural Heritage: multi-source and multi-scale data integration and processing in research and applications

Room: Conference Hall "Alberto Castoldi"

1 **Integrated Workflow for 3D modelling of Historic Architecture: A Multi-Sensor Approach**
Vincenzo Saverio Alfio (Polytechnic University of Bari), Domenica Costantino (Polytechnic University of Bari), Mathab Fallah (Polytechnic University of Turin), Alfredo Restuccia Garofalo (Polytechnic University of Bari), Massimiliano Pepe (University "G. d'Annunzio" of Chieti-Pescara) and Paolo Piumatti (Polytechnic University of Turin)

7 **UAS-based capacity building for enhancing minor archaeology**
Joel Aldrighettoni (University of Bergamo) and Maria Grazia D'Urso (University of Bergamo)

14 **High-Resolution Photogrammetric Survey of a Romanesque Mosaic Floor: A Comparative Analysis of UAS and a Custom-Built Acquisition System**
Barbara Fazion (Politecnico di Milano), Daniele Treccani (Politecnico di Milano), Andrea Adami (Politecnico di Milano) and Luigi Fregonese (Politecnico di Milano)

20 **New discoveries at the Castello Sforzesco in Milan: an integrated approach through 3D modelling and GPR survey**
Maurizio Porcu (Codevintec Italiana s.r.l.), Francesca Biolo (Politecnico di Milano) and Franco Guzzetti (Politecnico di Milano)

26 **Integrating geomatic high-detail surveying and thermography for the documentation of historical masonry**
Anna Forte (Università di Bologna), Francesca Trevisiol (Università di Bologna), Giulia Fiorini (Università di Bologna) and Gabriele Bitelli (Università di Bologna)

32 **Underground Surveying of the Porticus Minucia as a Basis for the Georeferencing of a Fragment of the Marble Plan of Rome (Forma Urbis Marmorea)**
Valerio Baiocchi (Sapienza University of Rome), Alessandri Luca (sapienza Università di Roma), Marta Baumgartner (Soprintendenza speciale Archeologia, Belle Arti e Paesaggio di Roma), Diego Blanco (archeogeos s.r.l.), Alessandro Bosman (CNR IGAG), Andrea Guaglianone (Independent researcher) and Felicia Vatore (Sapienza Università di Roma)

Session 1.2 - Non-destructive imaging and interferometric techniques for cultural heritage diagnostics and metrology

Room: Room 6 - First Floor

37 **Infrared and Terahertz Imaging for the Analysis of a Fresco Sample**
Emma Vannini (INO-CNR, University of Florence), Ilaria Catapano (IREA-CNR), Alice Dal Fovo (INO-CNR), Valentina Di Sarno (INO-CNR), Alessandra Rocco (INO-CNR), Pasquale Maddaloni (INO-CNR) and Raffaella Fontana (INO-CNR)

42 **2D and 3D optical techniques for manuscript analysis: diagnostics based on data integration**
Nicole de Manincor (University of Verona), Sara Mazzocato (University of Verona), Dumitru Scutelnic (University of Verona) and Claudia Daffara (University of Verona)

47 **Shearography and 3D scanning for assessing the strip lining in the case study: Pericles observes Phidias's artwork on the Parthenon, by Gaspare Landi**
Chiara Saltarelli (CNR-ISASI), Vito Pagliarulo (CNR-ISASI), Maria Rosaria Vigorito (Suor Orsola Benincasa University) and Melania Paturzo (CNR-ISASI)

Session 1.3 - Integrated Methods, Theories and Applications For Structural Health Monitoring And Assessment Of Ancient Constructions - PART I

Room: Room 7 - First Floor

Session 2.1 - From Composition to Conservation: Advanced Diagnostic Techniques for the Study of Ancient, Modern and Contemporary Painting Surfaces

Room: Conference Hall "Alberto Castoldi"

108 **Characterization of two vases from Centuripe**

Bianca Irene Carnesale (University of Milan), Giacomo Biondi (CNR, ISPC), Mario Colella (University of Pavia), Federica Giacobello (University of Milan) and Letizia Bonizzoni (University of Milan)

113 **Spectroscopic Investigation of a 17th-Century Illuminated Parchment from S. Maria di Montalto Church (Messina, Italy)**

Giuseppe Paladini (University of Messina), Francesco Caridi (University of Messina), Domenico Majolino (University of Messina), Lorenzo Pistorino (University of Messina), Paola Cardiano (University of Messina), Alessandra De Caro (Centro Regionale Progettazione e Restauro e per le Scienze Naturali ed applicate ai beni culturali), Gloria Bonanno (Centro Regionale Progettazione e Restauro e per le Scienze Naturali ed applicate ai beni culturali), Arcangela Valenti (Centro Regionale Progettazione e Restauro e per le Scienze Naturali ed applicate ai beni culturali), Enza Anna Passerini (Centro Regionale Progettazione e Restauro e per le Scienze Naturali ed applicate ai beni culturali), Giuseppe Sampino (Soprintendenza BB.CC.AA) and Valentina Venuti (University of Messina)

Session 2.2 - How To Preserve Outdoor Cultural Heritage: State-Of-Art, Challenges and New Perspectives

Room: Room 6 - First Floor

118 **Practical solutions to the biodeterioration dilemma: activity of Dittrichia viscosa extracts and its specialized metabolites on standard organism Raphidocelis subcapitata**

Alessandro De Rosa (University of Studies Suor Orsola Benincasa, Naples), Marco Morelli (University of Naples Federico II), Marco Masi (University of Naples Federico II), Alessio Cimmino (University of Naples Federico II), Andrea Carpentieri (University of Naples Federico II), Gaia Marzia Silvestre (University of Naples Federico II), Antonino Pollio (University of Naples Federico II) and Paola Cennamo (University of Studies Suor Orsola Benincasa, Naples)

124 **An integrated approach to the study of the architectural features of the theatre of Tyndaris**

Marco Sfacteria (University of Messina), Stefania Tuccinardi (University of Messina) and Marta Venuti (University of Messina)

129 **In-situ investigation of mortar fragments from the theatre of the archaeological area of Tindari (Sicily, Italy) through DRIFT and u-Raman techniques**

Giuseppe Paladini (University of Messina), Francesco Caridi (University of Messina), Domenico Majolino (University of Messina), Gabriele Lando (University of Messina), Paola Cardiano (University of Messina) and Valentina Venuti (University of Messina)

133 **Multi-Technique Characterization of Mural Paintings at the Santa Maria Gratia Plena Church in Bruzzano Vetere (Calabria, Southern Italy)**

Lorenzo Pistorino (University of Messina), Francesco Caridi (University of Messina), Giuseppe Paladini (University of Messina), Pasquale Faenza (G. Rohlfs Museum of the Calabrian Greek Language), Domenico Majolino (University of Messina) and Valentina Venuti (University of Messina)

Session 2.3 - Integrated Methods, Theories And Applications For Structural Health Monitoring And Assessment Of Ancient Constructions - PART II

Room: Room 7 - First Floor

138 **Historic centers between reconstruction and recovery. Urban planning considerations on a post-earthquake survey in Amatrice and Accumoli**

Francesco Fazzio (University of Perugia)

144 **Remote Sensing for Heritage Conservation and Structural Monitoring: The case of Wolvesey Castle, Winchester**

Efcharis Balodimou (University of West London), Nicoletta Bianchini (University of West London), Tamsin Withers (English Heritage, Engine House), Laden Husamaldin (University of West London), Moein Motavallizadeh Naeini (University of West London), Tesfaye Tessema (University of West London) and Fabio Tosti (University of West London)

150 **Experimental investigation of a masonry arch subjected to an asymmetric concentrated vertical load and validation via static and kinematic limit analysis**
Mario Fagone (University of Florence), Tommaso Rotunno (University of Florence), Natalia Pingaro (Politecnico di Milano) and Gabriele Milani (Politecnico di Milano)

155 **Optimization of CVAE parameters for the damage assessment of historic masonry buildings**
Ivan Roselli (ENEA) and Domenico Palumbo (ENEA)

160 **Time and frequency domain analysis of Etruscan pottery magnified videos**
Vincenzo Fioriti (ENEA), Eugenia Verrigni Petrei Castelli (ENEA), Alessandro Colucci (ENEA) and Ivan Roselli (ENEA)

Thursday, October 16

Session 3.1 - Damage and Radiological Risk Assessment: Diagnosis and Monitoring for the Restoration, Preventive Conservation, Usability and Maintenance of Cultural Heritage

Room: Conference Hall "Alberto Castoldi"

166 **Mineralogical Analysis of Viterbo Tuff Using X-Ray Diffraction and Raman Spectroscopy**
Giuliana Faggio (University Mediterranea of Reggio Calabria), Francesco Caridi (University of Messina), Daniele Chiriu (University of Cagliari), Stefania Da Pelo (University of Cagliari), Michele Guida (University of Salerno), Giacomo Messina (Università Mediterranea di Reggio Calabria), Maurizio Ponte (Università della Calabria), Silvestro Antonio Ruffolo (Università della Calabria), Domenico Majolino (University of Messina) and Valentina Venuti (University of Messina)

171 **Role of consolidants for limiting the radon exhalation rate in building materials of historical and artistic interest**
Francesco Caridi (University of Messina), Daniele Chiriu (University of Cagliari), Stefania Da Pelo (University of Cagliari), Giuliana Faggio (Università "Mediterranea" Calabria), Michele Guida (Università degli Studi di Salerno), Giacomo Messina (Università degli Studi di Salerno), Maurizio Ponte (Università della Calabria), Silvestro Antonio Ruffolo (Università della Calabria), Domenico Majolino (University of Messina) and Valentina Venuti (Università degli Studi di Messina)

176 **Historical urban centers built in tuff and indoor radon exposure**
Simona Mancini (University of Salerno), Serpil Aközcan Pehlivanoğlu (Kirklareli University), Natasa Todorovic (University of Novi Sad), Albina Cuomo (C.U.G.RI.), Domenico Guida (C.U.G.RI.) and Michele Guida (University of Salerno)

181 **Natural radioactivity content, radiological hazard and mineralogy evaluation of Pumice stone from Lipari, Sicily, Southern Italy: a case study**
Lorenzo Pistorino (University of Messina), Francesco Caridi (University of Messina), Giuseppe Paladini (University of Messina), Antonio Francesco Mottese (Università Mediterranea, Reggio Calabria, Italy), Domenico Majolino (University of Messina) and Valentina Venuti (University of Messina)

187 **Radon exhalation, natural radioactivity content and radiological hazard assessment for the Viterbo tuff stone: a case study**
Francesco Caridi (University of Messina), Daniele Chiriu (University of Cagliari), Stefania Da Pelo (University of Cagliari), Giuliana Faggio ("Mediterranean" University of Reggio Calabria), Michele Guida (University of Salerno), Giacomo Messina ("Mediterranean" University of Reggio Calabria), Maurizio Ponte (University of Calabria), Silvestro Ruffolo (University of Calabria), Domenico Majolino (University of Messina) and Valentina Venuti (University of Messina)

Session 3.2 - Chromatic Heritage: Exploring the Science of Pigments, Stones and Art Conservation - PART I

Room: Room 6 - First Floor

193 **[INVITED] Natural ultramarine in the Roman context of Volsinii (Bolsena, Italy): a multianalytical characterization**

Martina Bernabale (Sapienza University or Rome), Anna Candida Felici (Sapienza University or Rome), Pierfrancesco Atanasio (Sapienza University or Rome), Luca Buccini (Sapienza University or Rome), Daniele Passeri (Sapienza University or Rome), Marco Rossi (Sapienza University or Rome), Paolo Binaco (Museo Territoriale del Lago di Bolsena) and Danilo Dini (Sapienza University of Rome)

198 **Intelligent Workflow for Real Time and Automated Analysis of Historical Pigments**

Irene Ferrara (Università degli Studi di Catania, Italia), Paola Benedetta Castellino (Università degli Studi di Catania, Italia), Salvatore Gallo (Università degli Studi di Catania, Italia), Anna Maria Gueli (Università degli Studi di Catania, Italia), Giuseppe Politi (Università degli Studi di Catania, Italia) and Giuseppe Stella (Università degli Studi di Catania, Italia)

203 **3D Fluorescence Mapping: A promising Technique for the Analysis of the Degradation of Pigments**

Stefania Porcu (University of Cagliari), Michela Podda (University of Cagliari), Giovanni Brodu (University of Cagliari), Stefano Columbu (University of Cagliari) and Daniele Chiriu (University of Cagliari)

Session 3.3 - Multiscale And Multitemporal High Resolution Remote Sensing and Non-Destructive Testing For Archaeology And Monumental Heritage: From Research To Preservation - PART I

Room: Room 7 - First Floor

208 **New results from the GPR surveys at the area surrounding the Basilica at S. Croce in Gerusalemme, (Roma, Italy)**

Salvatore Piro (ISPC CNR)

213 **Multidisciplinary approach for the stability analysis of a historical hypogeum in the municipality of Cisternino in the Itria Valley (Puglia, Southern Italy), aimed at a refunctionalization and valorization of the site**

Maurizio Lazzari (CNR ISPC, Potenza), Davide Palma (Geophysics to GeoEngineering), Pierpaolo Moretti (Geophysics to GeoEngineering) and Valentina Leopizzi (Indipendent archeologist researcher, Lecce)

219 **GPR survey at the archaeological site of Heloros (Noto, Sicily)**

Davide Tanasi (University of South Florida), Rosa Lanteri (Parco archeologico di Siracusa, Eloro, Villa del Tellaro e Akrai), Vincenzo di Fiore (ISPC-CNR), Michele Punzo (ISPC-CNR), Daniela Tarallo (ISPC-CNR), Dora Francesca Barbolla (ISPC-CNR), Lara De Giorgi (ISPC-CNR), Ivan Ferrari (ISPC-CNR), Francesco Giuri (ISPC-CNR) and Giovanni Leucci (ISPC-CNR)

224 **From Point Clouds to Cultural Landscapes: Open-Source Machine Learning Applications for Archaeological UAV LiDAR segmentation**

Nicodemo Abate (CNR - ISPC), Antonio Minervino Amodio (CNR - ISPC), Maria Sileo (CNR - ISPC), Rosa Lasaponara (National Research Council - IMAA), Nicola Masini (CNR - ISPC), Gabriele Ciccone (CNR - ISPC) and Alessia Frisetti (CNR - ISPC).

229 **Discovery and study of "S.S. Egypte" shipwreck using remote sensing techniques, off north harbour of Patras city, Greece**

George Papatheodorou (University of Patras), Dimitrios Christodoulou (University of Patras), Xenophon Dimas (University of Patras), George Karelas (University of Patras) and Maria Geraga (University of Patras)

Session 4.1 - Old Solutions for New Problems: Innovative Multitechnical Strategies for Diagnostics on Peculiar Case Studies

Room: Conference Hall "Alberto Castoldi"

234 **A matter of materiality: the use of multi-analytical methods for reinforcing urban heritage**

Adi Sela Wiener (Bezalel Academy of Arts and Design, Jerusalem), Laura Medeghini (Sapienza University of Rome) and Gabriele Favero (Sapienza University of Rome)

240 **Exploring the Application of Explainable Neural Networks for the Petrographic Classification of Ceramic Samples from the Levant**

Sara Capriotti (Sapienza University of Rome), Alessio Devoto (Sapienza University of Rome), Donatella Genovese (Sapienza University of Rome), Silvano Mignardi (Sapienza University of Rome), Simone Scardapane (Sapienza University of Rome) and Laura Medeghini (Sapienza University of Rome)

246 **Unlocking the Information Potential of Lake Pigments through SERS and Chemometrics**

Adele Bosi (CNR-ISC), Camilla Marola (Sapienza University), Alessandro Ciccola (Sapienza University), Federico Marini (Sapienza University) and Claudia Fasolato (Sapienza University)

Session 4.2 - Chromatic Heritage: Exploring the Science of Pigments, Stones and Art Conservation - PART II

Room: Room 6 - First Floor

250 **XRF and Raman Spectroscopic Study of Wall Polychromes in the Saltworks Castle in Wieliczka**

Anna Klisińska-Kopacz (National Mueum in Krakow), Pamela Grajny-Brzezińska (Cracow Saltworks Museum in Wieliczka), Tomasz Wilkosz (National Mueum in Krakow), Michał Obarzanowski (National Mueum in Krakow), Klementyna Ochniak-Dudek (Cracow Saltworks Museum in Wieliczka) and Julio M. del Hoyo Meléndez (National Mueum in Krakow)

256 **Quantitative approaches for Fiber Optics Reflectance Spectroscopy (FORS)**

Ricardo Pedro Vicente Rojas (Sapienza University of Rome), Silvia Sotgiu (National Central Library of Rome), Véronique Cachia (National Central Library of Rome), Eugenio Delre (Sapienza University of Rome), Nicola Schiavon (Hercules Laboratory, University of Evora, Pal), Mauro Giustini (Sapienza University of Rome) and Mauro Missori (Institute of Complex Systems, CNR)

261 **Multi-technique archaeometric investigation of a XVII century illuminated parchment belonging to the S. Maria di Montalto Church (Messina, Italy)**

Giuseppe Paladini (University of Messina), Francesco Caridi (University of Messina), Domenico Majolino (University of Messina), Lorenzo Pistorino (University of Messina), Alessandra De Caro (Centro Regionale Progettazione e Restauro e per le Scienze Naturali ed applicate ai beni culturali, Italy), Gloria Bonanno (Centro Regionale Progettazione e Restauro e per le Scienze Naturali ed applicate ai beni culturali, Italy), Arcangela Valenti (Centro Regionale Progettazione e Restauro e per le Scienze Naturali ed applicate ai beni culturali, Italy), Enza Anna Passerini (Centro Regionale Progettazione e Restauro e per le Scienze Naturali ed applicate ai beni culturali, Italy), Giuseppe Sampino (Soprintendenza BB.CC.AA, Messina, Italy) and Valentina Venuti (University of Messina)

Session 4.3 - Multiscale And Multitemporal High Resolution Remote Sensing And Non-Destructive Testing For Archaeology And Monumental Heritage: From Research To Preservation - PART II

Room: Room 7 - First Floor

267 **Archaeological Remote Sensing at the Villa of Sette Bassi: Vegetation Index Analysis with Pléiades Neo Imagery**

Jessica Clementi (Sapienza University of Rome), Veronica Sanvito (Sapienza University of Rome), Stefano Roascio (Ministero della Cultura, Parco Archeologico dell'Appia Antica), Michele Reginaldi (Ministero della Cultura, Parco Archeologico dell'Appia Antica) and Paolo Mazzanti (Sapienza University of Rome)

273 **Can Vandalism Reshape the Way We Perceive Cultural Heritage?**

Fabrizio Terenzio Gizzi (CNR-ISPC), Cristina Cumbo (CNR-ISPC), Maria Rosaria Potenza (CNR-ISPC), Agata Maggio (CNR-ISPC), Antonio Minervino Amodio (CNR-ISPC) and Canio Alfieri Sabia (CNR-ISPC)

278 **ERT geophysical survey for Landslide Risk Management in Coastal Areas: Case Studies of Brovinje and Havišće (Croatia)**

Michele Punzo (ISPC-CNR), Dora Francesca Barbolla (ISPC-CNR), Giuseppe Cavuoto (ISPC-CNR), Vincenzo Di Fiore (ISPC-CNR), Daniela Tarallo (ISPC-CNR) and Giovanni Leucci (National Research Council).

282 **Water leaks as a hidden risk to cultural heritage sites: application of the TEAMWIRE project and the geophysical challenges**

Chiara Torre (University of Malta), Sebastiano D'Amico (University of Malta), Emanuele Colica (University of Malta), Julian Mamo (University of Malta), Lara De Giorgi (CNR-ISPC), Dora Francesca Barbolla (CNR-ISPC) and Giovanni Leucci (CNR-ISPC)

Session 5.1 - Monitoring techniques for cultural heritage damage assessment and control

Room: Conference Hall "Alberto Castoldi"

287 **EO-based products for risk assessment of cultural and natural heritage against climate and pollution impact**

Alessandro Sardella (CNR-ISAC), Ramiro Marco Figuera (SISTEMA GmbH), Stefano Natali (SISTEMA GmbH) and Alessandra Bonazza (CNR-ISAC)

292 **Environmental monitoring of The Grotto of the Animals: a case study for the SENNSE IoT platform**

Francesco Taurino (CNR - ISPC), Irene Muci (Università La Sapienza), Davide Zecca (CNR - ISPC), Cristiano Riminesi (CNR - ISPC), Grazia Tucci (Unifi, Firenze - Italia) and Alberto Bucciero (CNR - ISPC)

297 **From Thermal Signatures to Conservation Insights: A Fixed Camera Network Approach for Heritage Structure Health Monitoring**

Giandomenico Mastrantoni (Sapienza University of Rome), Jessica Clementi (Sapienza University of Rome), Antonio Molinari (Sapienza University of Rome), Ioannis Farmakis (Sapienza University of Rome) and Paolo Mazzanti (Sapienza University of Rome)

303 **Multi-scale non-invasive techniques for assessing instability conditions: examples from the Val di Cornia parks system (Tuscany, Italy)**

Tommaso Beni (University of Florence), Silvia Guideri (Parchi Val di Cornia S.p.A), Debora Brocchini (Parchi Val di Cornia S.p.A), Marta Coccoluto (Parchi Val di Cornia S.p.A), Diletta Borselli (University of Florence), Lorenzo Bonechi (National Institute for Nuclear Physics INFN), Sandro Gonzi (University of Florence), Irene Centauro (University of Florence), Anna Palamidessi (University of Florence), Vitaliano Ciulli (University of Florence), Raffaello D'Alessandro (University of Florence), Giovanni Gigli (University of Florence), Deodato Tapete (Italian Space Agency ASI), Veronica Tofani (University of Florence) and Silvia Bianchini (University of Florence)

309 **Application of Digital Photogrammetry in Damage Mapping on Facades of Historical Buildings**

Tallis Rubens (Universidade de São Paulo), Fabiana Oliveira (Universidade de São Paulo), Fabricio Costa (Oregon State University), Luciana Toledo (Pontifícia Universidade Católica de Campinas) and Ana Elisabete Jacintho (Pontifícia Universidade Católica de Campinas)

Session 5.2 - Advances and innovation in ancient building materials studies: interfacing Archaeology, Science, and Technology

Room: Room 6 - First Floor

315 **Geophysical Survey in the Presbytery of Tarragona Cathedral**

Albert Casas (Universitat de Barcelona), Josep Mª Macias (Institut Català d'Arqueologia Clàssica), Mahjoub Himi (Universitat de Barcelona), Andreu Muñoz-Virgili (Institut Català d'Arqueologia Clàssica), Aritz Urruela-García (Universitat de Barcelona), Andreu Muñoz-Melgar (Museu Diocesà de Tarragona), Albert Casas-Ponsatí (Universitat de Barcelona).

320 **València la Vella (Spain) and Late Antique Mortars: A Regional Geochemical Approach**

Manel Górriz I Villar (Universitat de València), Mirco Ramacciotti (Universitat de València), Iván Pérez Torralba (University of Valencia), Angel Morales Rubio (University of Valencia), Iván Fumadó-Ortega (Universitat de València), José María Macias Solé (Catalan Institute of Classical Archaeology), Albert Ribera (Catalan Institute of Classical Archaeology) and Gianni Gallello (Universitat de València)

326 **Multi-Technique Characterization of Mortars from Gammarth Villa (Tunisia)**

Manel Gorriz I Villar (Universitat de València), Mirco Ramacciotti (Universitat de València), Iván Fumadó Ortega (Universitat de València), Hamden Ben Romdhane (Institut National du Patrimoine, Tunis, Tunisia.), Angel Morales Rubio (University of Valencia) and Gianni Gallello (University of Valencia)

333 **XRD and PCA analysis of historic mortars from the Venetian Fortress of Bergamo (Italy)**
Renato Pelosato (Università degli Studi di Bergamo), Isabella Natali Sora (Università degli Studi di Bergamo), Virna Maria Nannei (Università degli Studi di Bergamo) and Giulio Mirabella Roberti (Università degli Studi di Bergamo)

Session 5.3 - General Session - PART I

Room: Room 7 - First Floor

339 **The Advent of Complex Metallurgy**
Yuval Goren (Ben-Gurion University of the Negev), Yotam Asscher (University of Haifa), Sariel Shalev (University of Haifa) and Danny Rosenberg (University of Haifa)

345 **Characterization of Early 20th Century Measurement Instruments: A Heritage Approach**
Emma Angelini (Politecnico di Torino), Margherita Bongiovanni (Politecnico Torino), Leila Es Sebar (Politecnico di Torino) and Federico Di Iorio (Fondazione Centro per la Conservazione ed il restauro dei Beni Culturali (La Venaria Reale))

351 **Preliminary Investigation into pre-Industrial Salt Production: an experimental approach**
Martina Sciortino (University of Trento), Alessia Santiglia (University of Milan), Monica Azzarone (University of Milan), Laura Magnano (University Cattolica), Giorgio Baratti (University Cattolica), Laura Santagostini (University of Milan) and Vittoria Guglielmi (University of Milan).

357 **Preserving the Past with Gamma Rays: Real Case Studies from the Montecassino Abbey Collection**
Beatrice D'Orsi (ENEA), Rocco Carcione (ENEA), Ilaria Di Sarcina (ENEA), Jessica Scifo (ENEA), Teresa Rinaldi (Sapienza University of Rome), Nicola Tangari (University of Cassino and Southern Lazio) and Alessia Cemmi (ENEA)

362 **Assessing material compatibility for restoration: An innovative approach to compare hydraulic properties of repair and historic mortars**
Salvatore Menta (University of Catania), Antonio Stroscio (University of Catania), Gaetano Ortolano (University of Catania), Roberto Visalli (University of Catania) and Cristina Maria Belfiore (University of Catania)

Session 6.1 - Archaeobotany and Palynology as Tools for Reconstructing Past Biodiversity, Ecosystems, and Landscapes

Room: Conference Hall "Alberto Castoldi"

367 **Natural vs anthropogenic constraints address changes of plant biodiversity in Italy during the Holocene**
Cristiano Vignola (Sapienza University of Rome), Alessia Masi (Sapienza University of Rome) and Laura Sadori (Sapienza University of Rome)

372 **The Long-Term Human-Mediated Success of Olive Trees in the Central Mediterranean: A Multiproxy Perspective**
Laura Sadori (Sapienza University of Rome), Jordan Palli (University of Tuscia, Viterbo), Sabina Fiolna (Freie Universität of Berlin), Monica Bini (University of Pisa), Federico Cappella (Sapienza University of Rome), Adam Izdebski (Max Planck Institute, Jena, Germany, Jagiellonian University in Krakow, Poland, University of Warsaw, Poland), Alessia Masi (Sapienza Univeristy of Rome), Scott Mensing (University of Nevada, Reno), Lorenzo Nigro (Sapienza Univeristy of Rome), Gianluca Piovesan (University of Tuscia, Viterbo) and Giovanni Zanchetta (University of Pisa)

376 **Measuring Millennial Biodiversity with Pollen: Archaeo-Data from Southern Italy**
Eleonora Clò (University of Modena and Reggio Emilia), Anna Maria Mercuri (University of Modena and Reggio Emilia), Jessica Zappa (University of Modena and Reggio Emilia), Cristina Ricucci (University of Modena and Reggio Emilia), Lorenzo Braga (University of Modena and Reggio Emilia) and Assunta Florenzano (University of Modena and Reggio Emilia)

382 **ARBOREA – A new georeferenced database for plant macro-remains from archaeological sites in Central Italy**
Claudia Moricca (Sapienza University of Rome), Erasmo Di Fonso (Sapienza University of Rome), Rachele Nicolini (Sapienza University of Rome) and Laura Sadori (Sapienza University of Rome)

Session 6.2 - General Session - PART II

Room: Room 6 - First Floor

386 **Biofilms on limestones specimens: laboratory tests implementing a non-destructive approach**
Davide Ripamonti (Università degli Studi di Milano), Emanuele Frabasile (Università Degli Studi di Milano), Alessia Marzanni (Università di Bolzano), Chao Gao (Norwegian University of Science and Technology), Chiara Bertolin (Norwegian University of Science and Technology), Villa Federica (Università degli Studi di Milano) and Nicola Gherardo Ludwig (Università degli Studi di Milano)

392 **Multi-technical non-invasive analysis to prevent deterioration in varnish-coated oil-paintings**
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From Surveying Techniques to a 3D GIS Geodatabase

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***Abstract* – Topographic surveys of buildings are usually performed with a variety of instruments and techniques. Then, dedicated software packages provide 3D metric models that can be enriched with a series of descriptive information. The user can choose between three different options: Building Information Modelling (BIM), Historical Building Information Modelling (HBIM) and 3D GIS Geodatabases.**

Particularly regarding cultural heritage buildings, information is extremely heterogeneous.

Geographic Information System (GIS) software packages facilitate the creation of georeferenced 3D environments and geodatabases. This allows linking all the information to the referenced metric building; it is useful for its maintenance, restoration and management. The surrounding environment, to which it is closely connected, plays an important role.

This paper describes how we built a GIS geodatabase of two 3D-modelled apses of a small church in the province of Bergamo. All the available information was gathered and linked in a 3D GIS scene.

I. INTRODUCTION

Surveying buildings, with laser scanners and photogrammetric techniques, provides the input required to construct 3D building models and derive a variety of 2D information, such as vertical and horizontal sections and raster images detailing the building's description at different resolutions. These products are managed with the help of dedicated SFW packages.

Then, the digital description of a building can be achieved in different ways, through BIM (Building Information Modelling) [1], HBIM (Historic Building Information Modelling) [2] and 3D GIS geodatabases.

BIM applications are typically adopted for new buildings, describing their structural elements with a defined library of parametric objects, representing construction components that contain not only geometric attributes, but also information about the physical properties of the applied materials. They are useful across a building's entire lifecycle, starting from its project and construction [3].

HBIM stems from BIM, as a standardised library of parametric objects is insufficient for the complex and diverse architecture of cultural heritage buildings [4]. It is useful for renovation, maintenance and conservation projects.

3D GIS geodatabases are collectors of heterogeneous information linked to 3D metric features inside GIS georeferenced scenes. In the case of heritage buildings and their ancient origin, they have undergone restoration, maintenance and interventions in time and also have a lot of related documentation which requires long and demanding research work. This material can be made by photos, projects, analyses and text documents of different origins and times. 3D GIS geodatabases become the most effective solution for storing all this heterogeneous material in a single environment and placing the referenced one in the proper spatial position. The advantage is also the possibility to make queries, define topological rules, enrich and update the collected information and add the products of new analyses and acquisitions. The spatial reference also becomes highly useful when considering the environment in which the building is located, and that deeply influences it with its changes and all kinds of phenomena occurring around it. This allows a better understanding of the building and to find the most suitable decisions for interventions, maintenance and restoration. This way, HBIM models and 3D GIS geodatabases represent the two faces of the same coin and their integration can be useful in many cases [5, 6].

It is also important to underline that the subject of BIM and GIS integration has been widely analyzed [7, 8, 9]. However, recently, a major step towards resolving this debate has been made thanks to a new partnership that allows users to integrate BIM products into GIS environments directly. Esri has partnered with Autodesk [10] to put GIS and BIM integration at the centre of construction projects. By accurately georeferencing BIM models, they are correctly placed in the real world. This alignment is essential for integrating BIM data with other geospatial data layers, such as maps, satellite imagery and environmental data [11].

The solution is provided by a relevant package called ArcGIS GeoBIM [12].

This is the first step, primarily focused on the project and management of buildings. However, in time, we hope to have new developments, also concerning a more complete and effective management of cultural heritage buildings and their heterogeneous information.

Going back to the digital description of a building, the first step, common to all three ways previously mentioned, is a topographic survey: surveying buildings, with laser scanners, GNSS receivers and photogrammetric techniques, provides the input required to construct georeferenced 3D building models and derive a variety of 2D information, such as vertical and horizontal sections and raster images detailing the building description at different resolutions. These products are managed with the help of dedicated SFW packages.

Drawing on previous studies [13 and mainly 14], this paper describes how it is possible to import a georeferenced 3D building model – in this case, of a cultural heritage building – into a GIS software package and establish connections between all the available information. This doesn't provide an HBIM model, but a 3D georeferenced geodatabase, into which all the building's information can be stored and linked to the structure under examination. This can be achieved by creating a geodatabase inside a 3D scene. Here, all the geometric information is referenced and therefore correctly placed, and the non-georeferenced information (such as images, texts, etc.) is linked via attribute tables to the corresponding geometric elements.

In the past, it was difficult to import and manage 3D models in GIS SFW packages, but this is now possible thanks to improved hardware and software.

Geographic Information Systems do not provide the advanced tools of BIM for modelling complex surface shapes of 3D objects. They allow, by now, only 3D basic elements to be edited, such as lines, points and simple 3D objects. On the other hand, GIS applications offer a major advantage: topological rules can be established among objects to evaluate their geometrical and spatial relationships. It is also possible to make queries. This way, the georeferenced 3D model of the building becomes a shell that, with the aid of a geodatabase, allows connecting, storing and updating all the available and new heterogeneous information.

Starting from these assumptions, this paper describes the steps followed to provide a 3D geodatabase of a test case: a small church in the province of Bergamo, which is called the Sanctuary of The Madonna dell'Olmo. The work was completed by taking the following steps: topographic surveys were performed, with varying instruments, and the survey data were processed. Three-dimensional georeferenced models were constructed and some 2D information (horizontal and vertical sections) was derived. Finally, a 3D GIS geodatabase was created in a suitable 3D GIS environment. The geodatabase collects all the referenced information and data without spatial reference, such as texts, images, etc.

Figure 1 outlines the steps required to complete the tasks mentioned above.

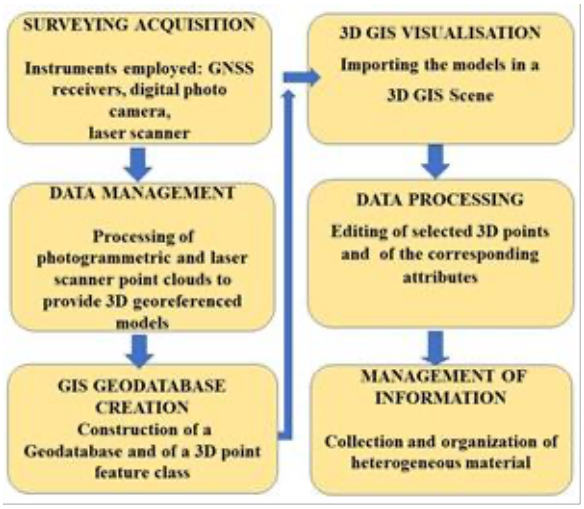

Fig. 1. Flowchart describing the steps taken in this work.

II. THE SANCTUARY OF THE MADONNA DELL'OLMO

The Sanctuary of the Madonna dell'Olmo, which dates to the fourteenth century, is in the southern part of the municipality of Verdellino, a village in the province of Bergamo [15, 16, 17]. The name of the church derives from an ancient legend about a miracle being performed by the Holy Mary through an elm tree once located in what later became the front yard of the church.

Fig. 2. The Sanctuary of the Madonna dell'Olmo.

The church, in Figure 2, was initially built in a rural area and then gradually absorbed by the industrial and residential settlement of Zingonia (around 1960), in the municipality of Verdellino. In 1400, the sanctuary already existed in its present form. It has not undergone major changes over the centuries.

In its outer part, there is a low wall that contains a grassy churchyard, a well, the rustic sacristy and a small bell tower. In the middle of the churchyard stands what remains of the secular elm (part of the trunk with a hollow inside), surrounded by a gate. Behind the elm tree is the entrance, preceded by a small porch that completely covers the façade. Inside, as shown in Figure 3, the sanctuary has a single nave divided into two bays by a pointed arch protruding from the wall.

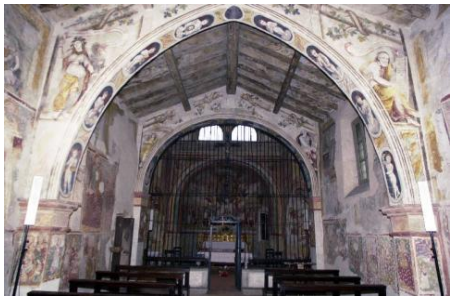

Fig. 3. The interior of the sanctuary [18].

A round arch leads into the presbytery, which has a rectangular plan with three small apses, a high altar and a minor altar on the right. The church is richly decorated with frescoes throughout its interior, on the ceilings, arches and walls. They have been painted in different periods by authors who are, unfortunately, unknown. These frescoes, which hold great historical value, earned the church a special grant in 1914, when the Superintendence of the Monuments of Lombardy declared that the Sanctuary of the Madonna dell'Olmo would be included among the national monuments of art [17].

Up to now, this sanctuary has been studied only from a historical and cultural point of view, and the existing documentation is limited to textbooks and images. Now, thanks to modern surveying techniques, it is possible to create thoroughly georeferenced geometric documentation of the building. This metric and referenced information will help facilitate the management of the building.

III. SURVEY AND DATA MANAGEMENT

All the instruments and software packages employed in this work and the resultant outputs achieved are summarized in Table 1.

Table 1. Instruments, SFW packages and outputs.

	Surveying	**GIS**
Acquisition Instruments	eSurvey E300 Pro GNSS receiver; Nikon D3300 reflex camera; Faro Focus Premium laser scanner	
Software Packages	Mercurio and Meridiana by Geopro; Scene by Faro; Riscan Pro by Regl; 3DF Zephyr by 3DFlow	ArcGISPro 3.1.3 by Esri
Resultant Outputs	3D Georeferenced Models	3D GIS Geodatabase

The outside of the church was surveyed using a Global Navigation Satellite System (GNSS) receiver, for georeferencing, and other instruments. A laser scanner, with a camera mounted on board, was used to acquire information on the interior and exterior of the building, while a photogrammetric survey targeted the major and right lateral apses inside the church. The laser scanner was used to survey the complete interior area, but not some side areas of the exterior or the roof. Further surveys could then be performed to complete the missing information.

A GNSS eSurvey receiver, the E300 Pro, was employed [19] to identify a set of points that could serve as the basis for georeferencing the products of the laser scanner and camera. For the interior analyses, we focused on the right side and the major apses of the presbytery. The photogrammetric survey was carried out with a Nikon D3300 reflex camera [20] with a 24.2-megapixel sensor, and the images were taken at a resolution of 6,000 × 4,000 pixels. In addition, a Faro Focus Premium laser scanner with a 13-megapixel camera mounted onboard was employed in the survey project [21].

The data were processed using multiple software packages: Mercurio and Meridiana [22] by Geopro, Scene [23] by Faro, Riscan Pro [24] by Regl and 3DF Zephyr [25] by 3DFlow. They allowed us to build a georeferenced (WGS84 UTM32N) laser scanner 3D point cloud for the interior part of the building and two dense photogrammetric 3D point clouds for the two apses. These clouds were then aligned, and finally, with the use of meshes and textures, two 3D georeferenced models were produced. In Figures 4 and 5, we can see (in Zephyr) the final 3D georeferenced models of the right side and major apses of the presbytery section of the sanctuary.

Fig. 4. The right lateral apse.

Fig. 5. The major apse.

It is worth noting that the resolution of the final models was set to the highest possible level. It follows, for example, that, for the 3D model of the major apse, the mesh is of 3,838,878 triangles.

In addition to the georeferenced geometric information, i.e. the two 3D models and horizontal and vertical sections, we collected textual information and images. The whole complex of material was then uploaded into a GIS software. Hence, both the georeferenced and non-georeferenced material facilitated the construction of a 3D geodatabase of the building within a GIS 3D environment, called scene.

IV. A 3D GIS BUILDING GEODATABASE

At this point, we were working inside the SFW package ArcGISPro, version 3.1.3, made by Esri [26]. The aim was to store all the available heterogeneous information, connected with the building, in a geodatabase. This way, it would be possible to easily learn what data are already available, to plan to enrich them with new acquisitions, and evaluate possible maintenance interventions.

The imported files contain the following information:

- two 3D georeferenced models of the right side and major apses of the sanctuary;
- available photos, text and pictures and new georeferenced data, such as vertical and horizontal sections.

We decided to create a geodatabase and a 3D point feature class, to consolidate all the information within the GIS environment. The 3D files were then imported into a 3D scene to provide a geometric referenced vision of the two apses. Figure 6 shows the two models and the volumetry of the surrounding buildings (visualised at their real Orthometric height), in the municipality of Verdellino. This shapefile was downloaded from the Lombardy Geoportal [27]. A topographic basemap, provided by Esri, was chosen as the background.

Fig. 6. The 3D referenced models in an ArcGISPro scene with the DBGT (Geo-Topographical Database) buildings.

Focusing, at first, on the major apse, an editing step allowed the selection of some points of interest and to link the corresponding information, such as images, texts and descriptions, inside the attribute table. Consequently, these points could be easily identified and selected in the 3D scene by clicking on special symbols.

Figure 7 shows, for a selected point (in cyan) of the major apse, in the 3D scene, the corresponding pop-up window, with the relevant information stored in the attribute table. If there is a preview image, one can click on it and view an enlarged version inside an image editing program.

Then, for each selectable point, we also added, in the attribute table, three fields (columns) which store, in different folders, the corresponding available and new information. They are named Literature (for books, articles, papers, letters, etc.), Pictures (for paintings, images, pictures, photos, etc.) and Analyses (for plans, projects, interventions, restorations, etc.). Each folder can then be organised in subfolders, according to the variety and amount of the available and new information. It is important to collect, keep and update this information in case of future analyses and works.

Two-dimensional georeferenced information derived from the models, such as horizontal and vertical sections, can also be correctly placed in a 3D GIS scene.

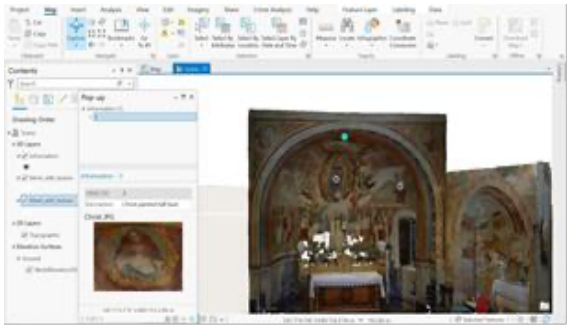

Fig. 7. The available information stored in an attribute table and linked to a selectable point on the 3D georeferenced model of the major apse, in an ArcGISPro scene.

V. DISCUSSION AND CONCLUSION

Thanks to the advantages offered by recent developments in survey instruments and software packages, it is nearly unthinkable to perform a building survey using only one type of instrument. The work described in this paper shows how the use of joint survey instruments and techniques can provide fast and thorough metric georeferenced information on a building.

Our goal was to create a 3D georeferenced geodatabase of a religious cultural heritage building. A GIS environment offers the advantage of providing a complete georeferenced description of a building's geometrical features, which can be enriched with associated heterogeneous information (texts, images, etc.). This is now possible, thanks to advancements in software and hardware. We have described how we were able to create a 3D geodatabase for two apses of the sanctuary.

The next step will be to enrich the database, following two different but parallel paths. The first will focus on the research, collection and reordering of all existing heterogeneous material that can be found. The second

will provide new georeferenced and non-georeferenced information, starting, for instance, with a survey of the exquisite ceiling frescoes of the two spans and the presbytery dome. This procedure will also be performed for the other frescoes on the walls, to build as many georeferenced 3D models as possible. These will then be connected to the geodatabase, with the corresponding information. As a further step, we plan to use a drone to acquire a comprehensive 3D georeferenced model of the building exteriors. Another task will be to perform a georadar survey of the floors inside the sanctuary and the outside areas at the front. It has been claimed, but not yet verified, that some hidden rooms and built areas could exist just below the sanctuary's interior and close to the premises.

As noted above, this will help to produce a 3D geodatabase, always updatable with both old and new data, that is useful for managing the building, for instance, by maintenance and possible restoration.

Geographical referencing also facilitates the analysis of the influence and possible problems related to the surrounding environment, such as atmospheric phenomena, air quality, soil texture and geology, seismic events, etc. It is important to consider the close relationship between a building and its surroundings and only georeferenced information can help achieve this purpose. In fact, at the sanctuary we studied, an issue with water infiltration had recently damaged the dome. Work is underway to repair the church and prevent future damage.

Besides, GIS environments are extremely flexible, allowing work at different scales, according to requirements. This way, it is possible to focus on large-scale particulars, with a high Level of Detail (LOD), or to consider a wider environment, at small-scale, with a reduced Level of Detail.

The OGC standard CityGML defines five LODs, ranging from 0 to 4, which state the amount of geometric and semantic information provided to describe a building. At LOD0, a 3D edifice is represented by its simple 2D footprint and, finally, LOD4 defines the interior features of an architecturally detailed 3D model [28].

GIS applications typically address territorial issues at a small scale; however, when they focus on specific analyses of a building at a large scale, the level of detail plays an important role. For this reason, it is crucial to decide the priorities of a project. If the purpose, for instance, is the study of a building within its environment, the building LOD can be low; otherwise, if the work is focused on the analysis of the walls of a crypt, the LOD must be higher. As said, GIS environments offer the advantage of being extremely flexible and allow working at different scales.

According to these assumptions, a building survey is performed with different instruments, from drones to laser scanners, which provide 3D models at different resolutions.

It has to be remembered, anyway, that only the integration of BIM and GIS is the best approach for a thorough description of a building, whose project and management are highly influenced by the surrounding environment. As seen above, this integration is now possible and, in time, it will hopefully evolve, also concerning the management of cultural heritage buildings and their legacy and new heterogeneous information.

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