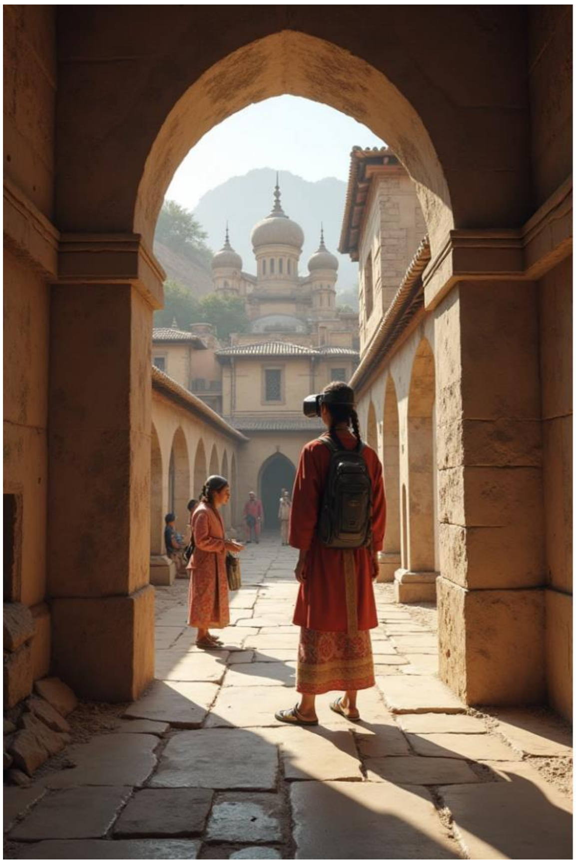
Book of Abstracts



Workshop on Advanced Visualization Tools in Heritage Science

13-15 March 2025 – ZAG, Ljubljana (Slovenia)

Preface

The aim of this workshop was to describe how to analyse and explore natural and cultural heritage materials in a novel and exciting way.

The authors of talks, demo/tutorials and posters provided the opportunity to familiarise with the most advanced tools for quantitative analysis and visualization of 3D & 4D images using non-destructive tomographic methods. The proposed imaging techniques, in fact, do not require to section, polish or chemically-treat the pristine samples and this represents a crucial aspect in the field of heritage science.

A full immersion in visualization technologies, including volume rendering, augmented and virtual reality, allowed participants to look at data from a different a more complete perspective.

The poster session, in the first day of the workshop, created a precious opportunity to informally discuss the work carried out by the presenters.

The final Round Table, in the third day of the event, allowed to critically talk about the most important topics highlighted in the Summary presentation given by Prof. Björn Nilsson. This discussion, as well as the social events organised during the first two days, represented nice and efficient networking activities paving the way to several new collaborations among participants.

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Chair and Organizers

Chairs: Lucia Mancini, ZAG-Slovenian National Building and Civil Engineering Institute, Ljubljana, (Slovenia) and Lidija Korat Bensa, ZAG & E-RIHS.si
Emanuel Larsson, Lund University & LINXS Institute of advanced Neutron and X-ray Science, Lund (Sweden)
Vito Mocella, CNR - ISASI, Napoli (Italy)
Rajmund Mokso, DTU Physics, Lyngby (Denmark)
Björn Nilsson, University Museum of Bergen (Norway) & LINXS

Topics

The workshop will encompass theoretical (lectures) and practical sessions and will cover the following topics:

- 3D/4D X-ray imaging techniques and data processing tools
- Advanced visualization techniques
- Virtual and augmented reality
- Natural and cultural heritage applications

Programme Committee

Mikael Fauvelle, Lund University (Sweden) & LINXS
Anna Fedrigo, ILL, Grenoble (France) & LINXS
Emanuel Larsson, Lund University & LINXS
Lucia Mancini, ZAG (Slovenia) & LINXS

Organising Institutions and Sponsors

ZAG - Slovenian National Building and Civil Engineering Institute (Slovenia)
LINXS Institute of advanced Neutron and X-ray Sciences, Lund (Sweden)
University of Bergen (Norway)
E-RIHS.si (European Research Infrastructure for Heritage Science – Slovenia)
RX Solutions, Chavanod (France)
sHERezad - Sustainable built heritage, ZAG horizontal research group
CNR/ISASI - Istituto di Scienze Applicate e Sistemi Intelligenti, Napoli (Italy)
DTU - Technical University of Denmark, Lyngby (Denmark).

Programme

13 March 2025

08.30 – 08.55 - Coffee and registration

08.55 – 09.10 – *Welcome and presentation of ZAG and Heritage Science theme at LINXS*, Lucia Mancini, ZAG (Slovenia).

09.10 – 10.10 – **Keynote speaker I**: - *Toward a unified platform for the digital twins of the specimens of natural history collections*, Patrick Semal, Royal Belgian Institute of Natural Sciences, Brussels (Belgium).

10.10 – 10.40 – *InfraVis: a Swedish national infrastructure for Visualization of Datasets*, Emanuel Larsson, Lund University & LINXS (Sweden).

10.40 – 11.00 – Coffee break

11.00 – 11.45– *SPAM: an open-source software for quantitative 3D image analysis, registration and correlation*, Olga Stamati, Université Grenoble Alpes (France).

11.45 – 13.00 – *Visit to ZAG Institute and laboratories*

13:00 – 14:30 – Light lunch & poster session

14:30 – 15:15 – *Neutron plus X-ray tomography for the study of coupled processes*, Alessandro Tengattini, ILL, Grenoble.

15.15 – 15.45 – Coffee break

15:45 – 17:00 – *Volumetric Data Analysis and Visualization with QIM3D* (talk+ demo), Felipe Delestro Matos, DTU (Denmark).

17:00 – 17:15 – *Open Q&A session*

19.00 – 23.00 – Social Dinner in Ljubljana city center

14 March 2025

09. 00 – 10.00 – **Keynote speaker II**: - *Towards Cross Virtuality Material Analytics - Design Studies on Augmented and Virtual Reality Applications and Combinations thereof Applied to Rich XCT Data*, Christoph Heinzl, University of Passau (Germany).

10.00 – 10.45 – *Dynamic Collections Plus: Advancing Archaeological Practices through 3D Visualization and Investigation Tools* (talk + demo/tutorial), Nicolò Dell'Unto, Lund University.

10.45 – 11.05 – Coffee break

11.05 – 11.40 – *Advanced X-ray Inspection Techniques for Efficient Defect Detection*, Joaquim Sanctorum, University of Antwerp (Belgium).

11.40 – 12.10 – *Cosmic rays for imaging cultural heritage objects*, Maxime Lagrange, Catholic University of Louvain (Belgium).

12.10 – 13.30 – Lunch break

13.30 – 15.00 – *From light-based tomography, to 3D reconstruction to Augmented Reality* (demo/tutorial), Emanuel Larsson, Lund University & LINXS.

15.00 – 15.30 – Coffee break

15.30 – 16.30 – *Immersive 3D visualization of CT data with Dragonfly* (talk + demo/tutorial), Anton du Plessis, Dragonfly Sales EMEAI (Canada).

16:45 – Bus transfer to Ljubljana city center

17:30 – 19:30 – Visit to the National Museum of Ljubljana and light dinner

15 March 2025

08. 30 – 09.30 – *Short presentations (7-8 min + Q&A)*

Presentation 1: *Synchrotron and neutron applications for cultural heritage-oriented palaeoecology and wetland archaeology—some questions posed by practitioners*, Paulina Blaesild, University of Gothenburg (Sweden).

Presentation 2: *Multi-analytical characterization of stone materials employed in the Val di Noto UNESCO sites (Sicily, Italy): Advanced Visualization Tools for Heritage Conservation*, Valeria Indelicato, University School for Advanced Studies IUSS Pavia (Italy).

Presentation 3: *From Virtual and Live Access to Prehistoric Rock Art – towards a Rock Art Research Infrastructure in Norway*, Trond Lødøen, University Museum of Bergen (Norway).

Presentation 4: *Alternative scanning geometries and visualization using the FleXCT system and the ASTRA toolbox*, Joaquim Sanctorum, University of Antwerp (Belgium).

Presentation 5: *X-ray microCT for heritage science*, Solene Valton, RX Solutions, Chavanod (France).

09:30 – 10.30 – *Summary talk & perspective work*, Björn Nilsson, University Museum of Bergen.

10:30 –11:30 – *Round table* (with coffee)

11.30 – 12.30 – Light lunch & farewell

Abstracts of oral and demo/tutorials presentations

Toward a Unified Platform for the Digital Twins of the Specimens of Natural History Collections

Patrick Semal[1], A. Mathys[2,3,1], J. Brecko[2,1], Y. Pollet[1], J.-M. Herpers[1], C. d'Udekem d'Acoz[1], F. Theeten[2], D. Vandenspiegel[2] & S. Jodogne[4]

[1] Royal Belgian Institute of Natural Sciences; Brussells, Belgium
[2] Royal Museum for Central Africa, Tervuren, Belgium
[3] ULiège, Liège, Belgium
[4] Université Catholique de Louvain, Louvain la Neuve, Belgium

The digitization of natural history collections is revolutionizing the preservation and utilization of biological and geological specimens. These collections, encompassing diverse ecosystems and time periods, are invaluable for scientific research, education, and conservation. However, physical specimens face challenges such as degradation, limited accessibility, and logistical difficulties. Digitization addresses these issues by converting specimens into high-resolution digital formats, preserving their integrity and making them widely accessible.
This presentation explores the development of a unified platform for the digital twins of natural history specimens, focusing on standardization, management, and accessibility of multimedia files. The platform aims to integrate various digitization efforts as the Distributed System of Scientific Collections (DiSSCo ERIC) in Europe. This initiative adheres to the FAIR principles (Findable, Accessible, Interoperable, and Reusable) to enhance research capabilities and interdisciplinary studies.
Key components of the platform include:

1. Digitization Techniques: High-resolution imaging, 3D scanning, and photogrammetry are used to create digital twins of specimens. These techniques ensure comprehensive documentation and accessibility for scientific research.
2. Metadata: The Darwin Core and ABCD standards for biodiversity data are managed by the institution CMS and DICOM is used for high-resolution and 3D imaging data. Links between CMS and Multimedia server are achieved using UUID/permalinks. This ensures quality, consistency, and interoperability of data.
3. Multimedia File Management: The platform utilizes the Open Source ORTHANC server, which supports various multimedia formats and provides a RESTful API for integration with other systems. Custom plugins and viewers were adapted or developed to enhance the visualization and analysis of digital specimens.
4. Interdisciplinary Collaboration: By providing a unified structure, the platform facilitates large-scale data analysis including access by AI and fosters collaboration among researchers, educators, and the general public.

The integration of digital technologies into natural history collections not only safeguards specimens but also democratizes access to data, enabling global research and education.
The proposed platform represents a significant advancement in the field, promoting the preservation and utilization of natural history collections in the digital age using Open Sources technologies. The proposed platform can easily be reused in a CH context.

InfraVis – a Swedish research infrastructure for visualization of tomographic datasets

Emanuel Larsson[1,2], J. Nirme[1], G. Alce[1], J. Ahlstedt[1], J. Eriksson[1], A. Sopasakis[1], C. Troein[1], J. Lindemann[1], A. Follin[1]

[1] Lund University, Lund, Sweden

[2] LINXS Institute for Advanced Neutron and X-ray Science, Lund, Sweden

InfraVis is a Swedish Research Infrastructure For Data Visualization from any scientific domain with to state-of-the-art visualization competence, support, equipment, training, and methods. Parts of InfraVis' focus is also aimed at visualizing volumetric datasets, e.g., emerging from X-ray and/or Neutron microtromography experiments. Our general pipelines include, image processing and machine learning-based segmentation methods [1] on High Performance Computing (HPC) clusters, advanced visualization using common 3D rendering, Virtual Reality (VR), Augmented Reality (AR), and immersive CAVE visualizations, which can reveal hitherto unknown aspects of the sample or data set, as well as smart VR tools for modifying complex datasets [2]. InfraVis also takes part in co-organizing joint research and educational activities [3,4].

[1] Segmenting Glomeruli and other Structures From Synchrotron X-Ray Microtomography Datasets, InfraVis – The National Research Infrastructure for Data Visualization, https://infravis.se/glomeruli/, Visited: 2024.12.26
[2] Butterflies In Virtual Reality: Developing Workflows For Efficient Morphological Segmentation And Analysis Of X-Ray Microtomography Datasets, InfraVis - The National Research Infrastructure for Data Visualization, https://infravis.se/butterflies-in-virtual-reality-developing-workflows-for-efficient-morphological-segmentation-and-analysis-of-microct-scans-lu/, Visited: 2024.12.26
[3] Workshop: Human Perception and Advanced Visualization of 3D Medical Imaging Data, co-organized by QIM, CIPA, InfraVis, DBI, LINXS, HALRIC, Event date: 29th of February, 2024, Copenhagen, Denmark, https://www.conferencemanager.dk/visualizationworkshop/conference, Visited: 2024.12.26
[4] Combining image processing with visualization inspired environmental scientists to analyse X-ray and neutron data, LINXS, https://www.linxs.se/news/2024/11/29/combining-image-processing-with-visualization-inspired-environmental-scientists, Visited: 2024.12.26

SPAM: An open-source software for quantitative 3D image analysis, registration and correlation

Olga Stamati[1]

[1] Université Grenoble Alpes, CNRS, Grenoble INP, 3SR, Grenoble, France

SPAM, the "Software for Practical Analysis of Materials" (https://www.spam-project.dev), is an open-source python package for quantitative data analysis for 2D images and 3D volumes that has developed around X-ray and Neutron tomography.

SPAM provides well-developed image registration tools as well as local, global and discrete Image Correlation methods and their associated strain calculation.
It also includes modules that allow for the segmentation of discrete objects in tomographic images and the computation of their geometrical quantities such as size, shape and orientation, as well as modules for generating unstructured FE meshes.
The user friendly and high-performance software, together with the detailed documentation and examples allow the users community to apply this code in a vast variety of applications including different scientific fields.
In this talk, the general architecture of SPAM will be presented, along with some example applications of quantifying descriptors of interests, as well as deformation processes in various materials.

Neutron plus X-ray tomography for the study of coupled processes

Alessandro Tengattini[1,2]

[1] Université Grenoble Alpes, CNRS, Grenoble INP, 3SR, Grenoble, France

[2] Institut Laue-Langevin (ILL), Grenoble, France

Coupled processes are ubiquitous in everyday life as well as engineering applications. For example, concrete is the second most widely used substance on Earth after water. The behavior of this material depends on complex, coupled processes occurring at the micro-scale and their interactions, which are very poorly understood. Full-field methods such as tomography lend themselves as ideal probing tools to explore the spatio-temporal evolution of these processes.
Specifically neutron imaging has proven essential to study several of these processes, and notably the role played by hydrogen-rich substances, such as water and hydrocarbons, within them. Recent developments have pushed the spatio-temporal resolution of neutron imaging as well as allowed for the acquisition of truly simultaneous neutron and x-ray tomographies. This combined use is uniquely powerful, thanks to the high complementarity of their contrast. It allows not only to study different aspects of processes (*e.g.*, the interdependence between the opening of cracks and water penetration) but even aids in the identification of the different phases comprising a sample as highlighted in Figure. 1.
This presentation will propose an overview of recent developments in the coupled use of neutron and x-ray imaging, focusing on how their joint use opens new venues in characterizing complex materials and coupled processes.

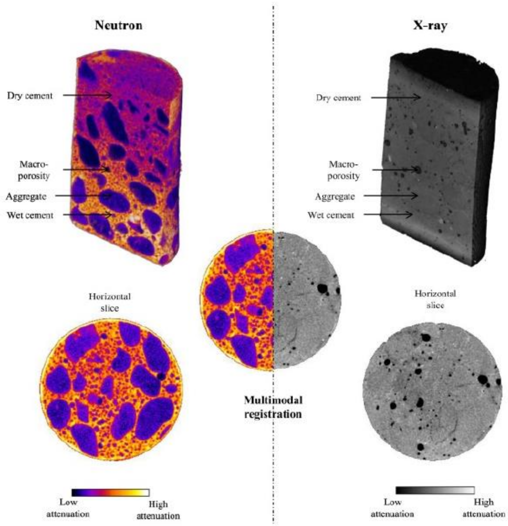

Figure 1: Example of the unique complementarity of information provided by neutrons and X-rays in the study of concrete

Volumetric Data Analysis and Visualization with QIM3D

Felipe Delestro[1]

[1] Technical University of Denmark, Kongens Lyngby, Denmark

The exploration of 3D volumetric images reveals intricate structures that demand advanced tools for effective analysis. While Python has become a cornerstone in the scientific community, the unique challenges of 3D image data often pose steep learning curves for newcomers and experts alike.
In this session, we'll introduce qim3d, a Python library designed to simplify 3D image analysis. It empowers researchers with streamlined data loading and manipulation, advanced image processing and filtering, and intuitive visualization of volumetric datasets, including large volumetric data.
The session combines a concise library overview with an interactive hands-on workshop. Attendees are encouraged to install qim3d beforehand and ensure access to a Jupyter notebook environment. Installation instructions are available at https://platform.qim.dk/qim3d/#installation.
Join us to discover how qim3d can enhance your 3D imaging workflows and transform complex data into insightful visualizations.

Towards Cross Virtuality Material Analytics - Design Studies on Augmented and Virtual Reality Applications and Combinations thereof Applied to Rich XCT Data

Christoph Heinzl[1]

[1]Faculty of Computer Science and Mathematics, University of Passau, Germany

The analysis and exploration of rich XCT data, including large primary data (e.g., single or series of volumetric XCT datasets) as well as secondary derived data (e.g., segmentation masks, labeled data, abstract or multivariate data), can be cumbersome in traditional desktop based visualization setups. Often domain specialists require an understanding of spatial data in its original data domain, considering abstract data on attributes of interest in various representations and levels of detail.

In this talk, cross virtuality analytics (XVA) will be addressed as an emerging field in materials science providing novel means for integrative analysis solutions. XVA enables visual analytics to explore data along the reality-virtuality continuum, individually or collaboratively. It targets to seamlessly integrate suitable visual metaphors, across different devices, and even supporting multiple users in solving a joint analysis task. In a number of design studies on virtual and augmented reality based immersive analytics techniques as well as a system integrating techniques along the reality-virtuality-continuum, this talk makes the claim, that cross virtuality analytics can provide novel insights into rich XCT data, which have not been possible before. As use-case of the presented methodology, the analysis of composite materials is addressed.

Dynamic Collections Plus: Advancing Archaeological Practices through 3D Visualization and Investigation Tools

Nicolò Dell'Unto[1]

[1] Department of Archaeology and Ancient History, Lund University, Lund, Sweden

Over the last two decades, visualisation and recording technologies have profoundly changed the way scholars perceive and interact with archaeological information. The integration of scientific visualisation techniques into archaeological workflows has enabled researchers to explore new ways of simulating and analysing the past, fostering theoretical advances and addressing new research questions. This paper examines the potential, limitations and future developments of 3D visualisation systems as a scientific medium for analysing and discussing archaeological interpretations. Through the presentation of case studies, it highlights how advanced visualisation techniques are used at different stages of archaeological investigation, from data acquisition and contextual analysis to hypothesis testing and public engagement. This overview underscores the critical role of 3D data in bridging the gap between archaeological research and practice, offering a path towards more integrated and efficient methodologies.

Advanced X-ray Inspection Techniques for Efficient Defect Detection

D. Iuso[1], J. De Beenhouwer[1], J. Sijbers[1], Joaquim Sanctorum[1]

[1] University of Antwerp, Antwerp, Belgium

Detecting defects in large or dense objects accurately can be challenging due to several image artifacts, of which beam hardening and scatter are the most prominent. In this talk, we present advanced methods to efficiently detect defect in these circumstances. We start from a situation where full CT data can be gathered and defect detection can be performed on the reconstructed volume by means of image segmentation. However, because of imaging noise and artifacts in the reconstructed images, basic segmentation methods (e.g. Otsu segmentation) perform very poorly. To circumvent this, 2D deep learning methods have been developed, but their performance is limited when inspecting full 3D datasets due to a lack of cross-slice consistency. In this work, we present a framework for using 3D neural networks that fruitfully use the volumetric information to reject noise. We demonstrate the use of both supervised and unsupervised methods to automatically detect defects such as pores and cracks. It is shown that unsupervised models perform better as compared to supervised methods without the need for a ground truth label image. When situations arise where full CT is not possible and one can only rely on a limited number of projection images, this approach does not apply. Fortunately, in such cases, defects can still be detected by exploiting prior knowledge about the object's surface mesh and its material composition. We demonstrate methods for automatic registration of the mesh model with only a limited number of recorded X-ray projections, allowing for defect detection in the projection space. Additionally, these results can be improved by including a compensation for scatter effects, which become more prominent in large and dense objects. We finally present a scatter compensation method that uses the mesh registration method to perform the scatter compensation in projection space, allowing for more accurate defect detection.

Cosmic rays for imaging cultural heritage objects

A. Giammanco[1], M. Al Moussawi[1], M. Boone[2], T. De Kock[3], J. De Roy[3], S. Huysmans[4], V. Kumar[1], Maxime Lagrange[1], M. Tytgat[5]

[1] Centre for Cosmology, Particle Physics and Phenomenology (CP3), Université catholique de Louvain, Louvain la Neuve, Belgium

[2] Ghent University Centre for X-ray Tomography, University of Ghent, Ghent, Belgium

[3] Antwerp Cultural Heritage Sciences (ARCHES), University of Antwerp, Antwerp, Belgium

[4] Stone Sculpture Studio, Conservation & Restoration, Royal Institute for Cultural Heritage (KIK-IRPA), Brussels, Belgium

[5] Inter-University Institute for High Energies (IIHE), Vrije Universiteit Brussel, Brussel, Belgium

Cultural heritage conservation more and more relies on non-destructive techniques and imaging methods based on the absorption or scattering of photons (X or $\gamma\gamma$-rays) or neutrons. Despite showing great imaging and material identification capabilities, their penetrating power becomes insufficient for large objects or objects composed of dense material (compact stone, metal).
Additionally, these techniques suffer from logistic constraints that restrict their use to relatively small objects that can be transported to imaging facilities. Although X-ray computed tomography (CT) systems and portable fast neutron sources start to be deployed for in-situ studies, they are subjected to radiation hazard regulations.
The high penetrating power of muons, the absence of radiation, and the possibility of designing portable detectors allow muon tomography to overcome the limitations mentioned above, and make it a good candidate for a new cultural heritage imaging technique. After discussing future use-cases of great interest for cultural heritage preservation, we present simulation studies of statues imaging whose aim is to identify in which regime the two existing muography techniques (absorption and scattering) are the most promising. We also discuss what technological and methodological developments are needed to make muography a reliable technique for cultural heritage applications.

From light-based tomography, to 3D reconstruction, to Augmented Reality

Emanuel Larsson[1,2], J. Ahlstedt[1], G. Alce[1]

[1] Lund University, Lund, Sweden

[2] LINXS Institute for Advanced Neutron and X-ray Science, Lund, Sweden

This tutorial will cover how to generate your own tomographic volumes, using a normal flash-light, a rotation stage and a camera, building on the principle of KBLT [5], to reconstructing the datasets using TomoPy [6] implemented in Jupyter Notebooks or using a Graphical User Interface (GUI), followed by generating a 3D mesh-file in ImageJ/Fiji [7], and optimizing it in Blender [8], followed by creating an Augmented Reality (AR) application on GitHub [9], than can be shared and run on your mobile phone.

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1 Larsson, Emanuel, Doğa Gürsoy, and Stephen A. Hall. "Kitchen-based light tomography-a DIY toolkit for advancing tomography-by and for the tomography community." *Tomography of Materials and Structures* 1 (2023): 100001. Link: https://doi.org/10.1016/j.tmater.2022.100001, visited: 2025.01.03
6 Gürsoy, Doga, et al. "TomoPy: a framework for the analysis of synchrotron tomographic data." *Journal of synchrotron radiation* 21.5 (2014): 1188-1193. Link: https://doi.org/10.1107/S1600577514013939, visited: 2025.01.03
7 ImageJ/Fiji, Link: https://imagej.net/software/fiji/, visited: 2025.01.03
8 Blender, Link: https://www.blender.org, visited: 2025.01.03
9 Gunter Alce, WebAR Tutorial, GitHub, Link: https://github.com/gunterAlce/webar-tutorial, visited: 2025.01.03

Immersive 3D Visualization of CT Data with Dragonfly

M. Emin[1], Anton du Plessis[2]

[1] Culmium d.o.o., RC eNeM d.o.o., Slovenia

[2] Comet Technologies Canada Inc, Montreal, Canada

This presentation explores the fusion of advanced 3D visualization techniques and deep learning to analyze CT data of natural and cultural heritage materials. Leveraging the capabilities of deep learning module in ORS Dragonfly, we will focus on semantic segmentation workflows that classify and interpret complex tomographic datasets with precision. Participants will discover how cutting-edge visualization technologies enhance the exploration of segmented data, offering intuitive insights. By combining these innovative tools, we aim to showcase how Dragonfly facilitates a deeper understanding of CT datasets, empowering researchers in heritage analysis to unlock new dimensions of discovery.

Poster presentations

Integrated 2D and 3D texture analysis of a mortar

Arianna Casarin[1,2], R. Repič[3], L. Mancini[3,4], G. Iezzi[1,2,5], F. Radica[1,2], A. Galderisi[6], M. Bravo[7], J. De Brito[7], G. Brando[1,2], M. Nazzari[5], P. Scarlato[5]

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[2] UdA-TechLab, Research Center, University "G. d'Annunzio" of Chieti-Pescara, Chieti, Italy

[3] Zavod za gradbeništvo Slovenije (ZAG), Ljubljana, Slovenia

[4] LINXS Institute of advanced Neutron and X-ray Science, Lund, Sweden

[5] Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma, Roma, Italy

[6] Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse (DiSTAR), Università degli Studi di Napoli Federico II, Napoli, Italy

[7] CERIS, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal

Characterizing geomaterials in Cultural Heritage through mineralogical, geochemical, and textural analyses is crucial for understanding raw material provenance and reconstructing ancient construction techniques [10]. These studies typically apply Earth Sciences methodologies, including 2D image analysis on polished slabs and thin sections to examine phases, voids, and particles [11].

To develop an analytical protocol for construction materials, a prismatic test mortar (16×4×4 cm) with a 1:2:4 water:cement:aggregate ratio was analyzed [12]. The aggregate, mainly quartz with minor alkali-feldspar and sheet silicates, had a sieved grain size distribution (φ vs wt.%, Fuller curve) of 0.2, 10, 33.3, 29.5, 19, and 8 wt.% for ≤0.125, 0.125–0.25, 0.25–0.5, 0.5–1, 1–2, and 2–4 mm, respectively [13]. A 4×4 cm thin section was studied via High-Resolution Scanner (HRS), Transmission Optical Microscope (TOM), and Scanning Electron Microscope (SEM), capturing the smallest and largest phases and clasts.

The 2D analyses quantified: i) cement-to-aggregate ratios, ii) cement paste distribution, and iii) clast size, that were compared to 3D sieve-derived data. HRS provides rapid, qualitative phase identification but is limited to transparent phases (e.g., quartz). TOM overestimates cement (54.3% vs. 41.7% by SEM) and underestimates aggregates (44.7% vs. 45.1% + 11.4% by SEM), while pore areas are comparable (1.0% vs. 1.8% by SEM). SEM offers superior textural resolution but is more time-consuming.

To validate these 2D results, 3D microfocus X-ray computed tomography (μCT) was applied, providing a comprehensive dataset and refining 2D assessments. These complementary methods, particularly the non-destructive μCT, are proposed for future studies on archaeological construction materials.

[10] Artioli G. & Oberti R., (2019), Mineralogical Society of Great Britain and Ireland, https://doi.org/10.1180/EMU-notes.20
[11] Higgins M.D., (2006), Cambridge University Press, https://doi.org/10.1017/CBO9780511535574
[12] Radica F. et al., (2024), *Constr. Build. Mater.* 453, https://doi.org/10.1016/j.conbuildmat.2024.139033
[13] Galderisi A., et al., (2023), *Materials* 16(7), https://doi.org/10.3390/ma16072855

Multi-analytical characterization of stone materials employed in the Val di Noto UNESCO sites (Sicily, Italy): Advanced Visualization Tools for Heritage Conservation

Valeria Indelicato[1,2,3], S. Mineo[2], G. Pappalardo[2], G. Lanzafame[2], R. Visalli[2], R. Maniscalco[2], E. Fazio[2], R. Cirrincione[2], R. Punturo[2,3]

[1] Department of Science, Technology and Society, University School for Advanced Studies IUSS Pavia, Pavia, Italy

[2] Department of Biological, Geological and Environmental Sciences, University of Catania, Catania, Italy

[3] Institute of Environmental Geology and Geoengineering (IGAG-CNR), Rome, Italy

The "Late Baroque towns of the Val di Noto" (Hyblean Plateau, southeastern Sicily), listed as UNESCO World Heritage sites, are a remarkable example of post-seismic reconstruction following the 1693 earthquake. These towns are characterized by a unique bichromatic architecture, derived from the use of either sedimentary (i.e. Hyblean limestones) and magmatic rocks, reflecting the close relationship between building material and geological context. However, prolonged exposure to atmospheric agents (e.g. rain, wind, solar radiation, aggressive atmospheric pollutants, freeze-thaw cycles, crystallization of saline solutions, and growth of organisms) has led to significant weathering and deterioration of these materials, affecting both durability and aesthetic integrity of the buildings.

In this study, we conducted a multi-analytical investigation of three main lithotypes (i.e., Noto Stone, Pitchstone and Etnean lavas) commonly employed as building materials in the Val di Noto towns. Specifically, our approach included petrographic, microstructural, engineering-geological and petrophysical (focusing on porosity and seismic behaviour) analyses alongside the observation of the deterioration forms developed in the buildings. The integration of traditional analytical techniques with innovative ones, such as three-dimensional (3D) fabric analysis using synchrotron radiation X-ray microtomography (SR-μCT) and Infrared Thermography (IRT), highlighted the complementary role of these technologies in characterizing the internal structure of stone materials, allowing us to establish a clear relationship between microstructural features and weathering forms observed in cultural heritage.

In conclusion, our study underscores the importance of combining traditional analytical techniques with advanced visualization technologies to develop a valuable tool for conservation and restoration strategies, contributing to the long-term preservation of cultural heritage.

3D Modeling of Cultural Heritage: Between Aesthetics and Science

Alen Iršič[1], L. Slak[1]

[1] University of Ljubljana, Ljubljana, Slovenia

In today's world, visualization technology has become increasingly accessible and easy to use. With the rapid advancement of software and hardware, more and more digital reconstructions of historical sites and objects are being produced. However, many of these visualizations lack a solid research foundation. They are often created primarily for their aesthetic appeal rather than as scientifically accurate representations. This trend leads to misleading interpretations of cultural heritage, where historical accuracy is sacrificed for artistic expression. While such visualizations may attract public interest, they fail to provide reliable insights into the past and can even contribute to the spread of misconceptions about historical architecture and artifacts.

To ensure accuracy and reliability, our approach to 3D modelling follows a strict and well-defined methodology. The process begins with an in-depth study of the available literature, including historical documents, architectural plans, and relevant academic research. This initial phase provides a foundational understanding of the subject and helps establish a clear framework for further investigation. Based on this research, detailed architectural plans are drawn, forming the blueprint for the 3D reconstruction. These plans are then supplemented with modern technological tools, such as LiDAR scanning, field surveys, building analysis, and geophysical investigations. Each piece of data is carefully examined and cross-referenced to eliminate uncertainties and ensure that the model reflects the most accurate representation possible. Only once all these steps are completed and supported by sufficient evidence does the actual 3D modelling process begin. This approach ensures that the final model is not just a visually appealing representation but a scientifically justified reconstruction.

The significance of accurately created 3D models of cultural heritage cannot be overstated. They serve as valuable tools for researchers, historians, and conservationists, aiding in the study, preservation, and restoration of historical structures. Additionally, they provide an engaging way to educate the public, allowing people to explore and understand cultural heritage in ways that traditional documentation cannot offer. These models also act as digital archives, preserving historical knowledge for future generations and ensuring that even if a physical structure is lost due to natural decay or destruction, its legacy remains intact. By prioritizing accuracy and methodological rigor, 3D models become more than just artistic representations—they become vital scientific documents that contribute to the ongoing study and safeguarding of our shared history.

Combination of X-ray microtomography and 3D printing for the digital preservation and production of replicas and museum exhibits of cultural heritage objects

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3D printing has become widely accepted for the digital preservation, restoration and examination of cultural heritage artifacts. However, surface scans alone are not sufficient for a large number of complicated biological objects such as bones, animals or wood. These pieces have a fragile and detailed internal structure and need to be examined using X-ray microtomography. In this research project, we are investigating the use of X-ray microtomography to generate data for 3D surface models with details of the exterior and interior. The ultimate goal is to print true-to-scale 3D versions in which even small details are easily recognisable. Three artefacts are presented, starting with the flute from the Divje babe I cave (Slovenia), the oldest musical instrument in the world, a treasure of global significance and proof of the existence of music among Neanderthals [1]. The replica is on display in the National Museum of Slovenia (Figure 1). The second example is the narrow-necked cave beetle ('Leptodirus hochenwartii') from the entomological collection of Schmidt [2,3]. Based on the three-dimensional digital model created by the ZAG 3DXIM team, MA-3D Design printed an extremely enlarged physical model that is two metres long and bears a remarkable morphological resemblance to the real beetle, as all details of the beetle are painted in its original colour. The model is part of the permanent exhibition at the Natural History Museum of Slovenia (Figure 2). The third example is the Carniolan honeybee [4], which delighted visitors to the Expo in Dubai in 2022. These national treasures provide a broader understanding of the possibilities and capabilities of both techniques and how they can benefit researchers and local museums by connecting different scientific disciplines from archaeology to art

[1] https://www.divje-babe.si/en/the-neanderthal-flute/
[2] https://www.pms-lj.si/razstava/hroscek-drobnovratnik/
[3] https://www.zag.si/zag-sodeloval-pri-pripravi-modela-jamskega-hroscka/
[4] https://www.gov.si/en/news/2022-02-04-gigantic-carniolan-honey-bee-enthuses-dubai-expo-visitors/

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InfraVis – a Swedish research infrastructure for visualization of tomographic datasets

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InfraVis is a Swedish Research Infrastructure For Data Visualization from any scientific domain with to state-of-the-art visualization competence, support, equipment, training, and methods. Parts of InfraVis' focus is also aimed at visualizing volumetric datasets, e.g., emerging from X-ray and/or Neutron microtromography experiments. Our general pipelines include, image processing and machine learning-based segmentation methods [14] on High Performance Computing (HPC) clusters, advanced visualization using common 3D rendering, Virtual Reality (VR), Augmented Reality (AR), and immersive CAVE visualizations, which can reveal hitherto unknown aspects of the sample or data set, as well as smart VR tools for modifying complex datasets [15]. InfraVis also takes part in co-organizing joint research and educational activities [16,17].

[14] Segmenting Glomeruli and other Structures From Synchrotron X-Ray Microtomography Datasets, InfraVis – The National Research Infrastructure for Data Visualization, https://infravis.se/glomeruli/, Visited: 2024.12.26

[15] Butterflies In Virtual Reality: Developing Workflows For Efficient Morphological Segmentation And Analysis Of X-Ray Microtomography Datasets, InfraVis - The National Research Infrastructure for Data Visualization, https://infravis.se/butterflies-in-virtual-reality-developing-workflows-for-efficient-morphological-segmentation-and-analysis-of-microct-scans-lu/, Visited: 2024.12.26

[16] Workshop: Human Perception and Advanced Visualization of 3D Medical Imaging Data, co-organized by QIM, CIPA, InfraVis, DBI, LINXS, HALRIC, Event date: 29th of February, 2024, Copenhagen, Denmark, https://www.conferencemanager.dk/visualizationworkshop/conference, Visited: 2024.12.26

[17] Combining image processing with visualization inspired environmental scientists to analyse X-ray and neutron data, LINXS, https://www.linxs.se/news/2024/11/29/combining-image-processing-with-visualization-inspired-environmental-scientists, Visited: 2024.12.26

With Tomography we can See More than a Lump of Sediment

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Neutron radiography, neutron tomography, synchrotron tomography, and phase contrast micro-CT are well-established techniques in cultural heritage studies. These imaging modalities have significantly transformed the examination and analysis of morphology, with museums increasingly integrating them for various purposes, including digital documentation and analytical strategies.

MicroCT's capability to capture diagnostic features has been employed to examine a lump of sediment adhering to the skull of a burial from the Upper Palaeolithic cave of S. Maria d’Agnano (Ostuni, Brindisi). TomoLab scans provided access to valuable information embedded within the sediment of a burial dating back approximately 30,000 years. The tomography revealed remains trapped within the archaeological sediment that would have otherwise remained undetected, while ensuring they remained untouched and uncontaminated. The scans identified a perforated shell, likely part of the skull cap that covered the Lady of Ostuni. This unexpected occurrence originates a further research design that involved environmental DNA metabarcoding (on going).

Computed tomography enables the creation of digital storytelling, bringing new life to a "forgotten" museum collection through analytical techniques.

The work briefly described above holds significant value for museum collections and, more broadly, for the vast informational potential of stored records. It paves the way for molecular analyses that can further investigations into past human behaviors and funerary practices. Since molecular studies are invasive, microCT scanning offers a non-destructive alternative by creating virtual models, preserving the original artifacts for future generations while providing high-resolution 3D data for research and analysis. This technique enables the creation of virtual, untouched specimens that facilitate the preservation, sharing, and study of objects, whether or not they hold aesthetic, historical, scientific, or social significance within cultural heritage.

3DXIM – the 3D X-ray Imaging Center at ZAG

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ZAG, is the only research institution in Slovenia that has been working in the field of X-ray computed microtomography (XmCT) for more than 12 years, and the only one using this technology in the field of sustainable construction solutions, including cultural heritage protection and energy storage.
In the Department of Materials, a 3D X-ray imaging center (3DXIM) is operational equipped with two XmCT scanners and a computational laboratory for processing, analysis and visualization of the obtained 3D data. Thanks to the available X-ray energy range and mechanical design, these instruments allow analysing, with a non-destructive approach and in the 3D domain, a wide range of materials in terms of chemical composition, density and sizes, operating both in static and dynamic (4DCT) modes. Thanks to the 4DCT approach, phase and morphotextural modifications under variable environmental conditions or upon applied stress are studied.
An important field of application of this technology is related to the use of 3D printing in combination with bio-products and bio-inspired structures, representing a pivotal topic at ZAG.
The multi-modal and multi-scale investigation of pathological phenomena in concrete to increase the lifetime and safety of building structures as well as corrosion and anticorrosion processes, are additional important applications at ZAG together with the development and quality control in the pharmaceutical, automotive, construction, electronics, metallurgical industries and the digitisation of important heritage science materials in museums and private collections. These studies are complemented by synchrotron radiation and neutron-based imaging experiments, thanks to the expertise matured in this field by several members of the 3DXIM center.
The facilities available in the center are also open for training and education of researchers, allowing to use state-of-the art imaging modalities to investigate objects from the sub-mm up to the meter scale achieving a maximum spatial resolution of 400 nm on mm-sized objects.

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Recent advances in enhanced epithermal neutron imaging for elemental and isotopic mapping

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Recent advances in an energy-selective neutron imaging method at the ISIS Neutron and Muon Source enable to establish the Neutron Resonance Transmission Imaging (NRTI) as a promising powerful method for conducting elemental and isotopic mapping with enhanced contrast.
NRTI is a non-destructive nuclear technique based on resonant neutron absorption, which merges sensitivity to elemental and isotopic composition with detailed morphological 2D data by exploiting the epithermal neutron flux available at the INES instrument of ISIS. NRTI is particularly promising for Cultural Heritage applications, especially when used alongside other techniques to provide comprehensive information about archaeological artefacts' composition and crystalline structure. An Heritage Science study is presented to demonstrate the effectiveness of NRTI in the investigations of heterogeneous artefacts, specifically focusing on excavation finds that provide the earliest evidence of ancient brass production in Milan, Italy, during Roman times. Moreover, in the framework of the CHNet_BRONZE project, founded by INFN, we are optimsing the NRTI for quantitative application on archaeological artefacts made of copper alloys.
Another successful application of this imaging technique has been the elemental mapping of meteorites, a heterogeneous class of samples typically classified through average destructive quantification and petrological observation, and generally, limited to their surface. Neutron techniques allowed the study of the bulk part of the sample without causing significant damage. In this context, the application of Neutron Resonance Transmission Imaging (NRTI) for meteorite characterisation is proposed as part of a non-destructive protocol under development.
Finally, the potential of NRTI for isotopic imaging will be discussed.

3D imaging showdown: A Comparative Study of high-resolution 3D Imaging Techniques for Museum Collections

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Museums continually seek innovative and efficient methods to accurately document their collections, enabling better digital preservation and broader sharing. Capturing precise 3D surface models of objects with intricate details, such as engravings, remains a challenging task.

This study investigates the potential of the Keyence VR-5200, a one-shot 3D microscope, for reconstructing highly detailed 3D models of small / medium artifacts by combining scans captured from multiple angles. The results are compared with those obtained using 3D reconstruction based on micro-computed tomography, high resolution structured light surface scanner and photogrammetry.

Our comparison evaluates the cost, efficiency, and quality of detail in the reconstructed 3D outputs, providing insights into the advantages and limitations of each approach.

The 3D Imaging Center at DTU

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The 3D Imaging Centre, 3DIM, at DTU is a competence center for X-ray and neutron imaging. Its activities spread over Denmark, Max IV and ESS in Sweden and ESRF in France. X-ray micro and nano 3D imaging is the main method associated to the development we do at synchrotron and laboratory instruments. 3DIM is home to a Danish national facility, DANFIX: a 900 m2 laboratory with room for 10 CT scanners. The facility is used for research and education within a broad range of natural, technical and health disciplines. Also it supports the digitization of natural and cultural heritage in Denmark. Some of the latest activities in the field of cultural heritage is a CT scan of Rembrandts portrait of a 39-year-old lady from Nivaagaards Malerisamling, supporting a dendrochronological analysis to explore the artwork's history or the digital unfolding of one of the biggest golden necklaces found in Vindelev. DANFIX is open for researchers and educators worldwide, offering the newest technology in 3D scanning of small objects down to 200 nm spatial resolution in phase contrast mode or for large objects with up to 600 kV source.

X-ray microtomography as a non-destructive evaluation technique for distinguishing and characterizing unique or rare objects

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Non-destructive access to the internal information of an object is a constant problem in many fields. In the past, many scientific fields have had the luxury of serially sectioning specimens to explore their internal structure, but this is not always possible with unique or rare objects in the field of heritage science. X-ray computed microtomography is a powerful imaging technique that is now widely used to characterise all types of objects, regardless of the scientific field. The use of modern non-destructive techniques in the examination and/or analysis of works of art and museum objects is very important and almost indispensable for conservators, restorers and archaeologists.

Here we present a non-destructive evaluation technique, namely X-ray microCT scanning (µXCT), to analyse and evaluate historical artefacts before destructive analysis is performed on such objects. ZAG has been providing important µXCT data for more than a decade, enabling researchers to reveal the hidden features of their samples, especially when the technique is needed for highly degraded and often fragile objects. The case studies are from Slovenian archaeological sites with varying states of preservation, and the results show the multidisciplinary investigation between different institutions. Three artefacts will be presented, starting with the Enigma M4 from the minesweeper R 15 [18], the Rattles from Dežmans lake dwellings in the Ljubljana Marshes [19] and the Palaeolithic wooden point from the Ljubljanica River, where the water-saturated wooden artefact had to undergo conservation treatment. To investigate these changes, a series of surface-based 3D models were created and compared - before, during and after the conservation process [20]. For museums, the technique also provides a digital copy of the artefact that can be shared globally, facilitating dissemination and reducing potential damage to the original artefact by providing an alternative to physical handling of the artefact.

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The authors gratefully acknowledge the financial support of the Slovenian Research and Innovation Agency (research core funding No. P2-0273 and No. I0-0032).

[18] Gaspari A. et al., (2023), Inštitut IRRIS za raziskave, razvoj in strategije družbe, kulture in okolja, https://doi.org/10.19233/ASHS.2023.01

[19] Turk P. et al., (2018), Ropotulje z Dežmanovih Kolišč Na Ljubljanskem Barju: Prispevek k Arheologiji Zvoka, Argo 61(2), 10-17

[20] Puhar G. et al., (2022), *Sensor* 22(6), https://doi.org/10.3390/s22062369

High energy X-ray computed tomography at CEITEC

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X-ray computed tomography (CT) is a well-established technique in heritage science for its non-destructivity and structural 3D visualization. This technique is well affordable by various laboratory devices, called microCT, as it can reach a resolution at the level of a few microns. These devices have limits in sample size thanks to their compact cabinet and fine X-ray source. For large-sized or metallic samples, CT with a large internal room and X-ray sources based on 450 kV accelerating voltage technology is the solution. These types of devices are generally presented by an increased penetration property but also not so fine resolution as microCT. This is overcome by a new type of source that has both advantages, keeping the power, and preserving the resolution. The presentation is going to elaborate on the possibilities of this device and demonstrate it on a high-tech industrial part.

Short talks

Synchrotron and neutron applications for cultural heritage-oriented palaeoecology and wetland archaeology—some questions posed by practitioners

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Wetland archaeological sites commonly offer extraordinary preservation conditions for organic matter, environmental proxies and humanly produced ecofacts. Since organic artefacts are unique in character but also found in various stages of preservation and fragility once excavated, wetland archaeological materials pose challenges as their unmeasured research potential is met with various extraction, conservation and preservation hazards. New and explorative measurement tools such as (micro)imaging tomography or elemental synchrotron/neutron classification today offer various non-destructive methods for archaeology; for the purpose of *i*. imaging raw- or combined materials for past tool manufacturing to the determination of plant taxa in ecofact production, or *ii*. for geochemical/elemental measurements of artefact surfaces/interiors or soils encasing such materials, for comparison with environmental proxies, exhibit great potential for (wetland) archaeological questions spanning conservation to the understanding of past human–environment relations. Within the adjacent field of palaeoecology, different questions may be posed as common analytical tools are restricted to qualitative and/or quantitative estimates of taxa composition. The potential to expand these studies to include internal structures of stratigraphical sequences, as opposed to standardized protocols of pre-classifying, cleaning and extracting plant elements from isolated units, may offer insight into various aspects of site development and local ecological functions. Nevertheless: the potential of micromorphological in-situ classification of sediments irrefutably pushes unexperienced research systems and workflows towards the brink of uncertainty; how do we approach materials in exploratory ways without clear directives at hand in an initial stage? What is required of the equipment to achieve such goals? How do we explore aspects of a material that is yet unknown—where to start?

Multi-analytical characterization of stone materials employed in the Val di Noto UNESCO sites (Sicily, Italy): Advanced Visualization Tools for Heritage Conservation

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The "Late Baroque towns of the Val di Noto" (Hyblean Plateau, southeastern Sicily), listed as UNESCO World Heritage sites, are a remarkable example of post-seismic reconstruction following the 1693 earthquake. These towns are characterized by a unique bichromatic architecture, derived from the use of either sedimentary (i.e. Hyblean limestones) and magmatic rocks, reflecting the close relationship between building material and geological context. However, prolonged exposure to atmospheric agents (e.g. rain, wind, solar radiation, aggressive atmospheric pollutants, freeze-thaw cycles, crystallization of saline solutions, and growth of organisms) has led to significant weathering and deterioration of these materials, affecting both durability and aesthetic integrity of the buildings.

In this study, we conducted a multi-analytical investigation of three main lithotypes (i.e., Noto Stone, Pitchstone and Etnean lavas) commonly employed as building materials in the Val di Noto towns. Specifically, our approach included petrographic, microstructural, engineering-geological and petrophysical (focusing on porosity and seismic behaviour) analyses alongside the observation of the deterioration forms developed in the buildings. The integration of traditional analytical techniques with innovative ones, such as three-dimensional (3D) fabric analysis using synchrotron radiation X-ray microtomography (SR-μCT) and Infrared Thermography (IRT), highlighted the complementary role of these technologies in characterizing the internal structure of stone materials, allowing us to establish a clear relationship between microstructural features and weathering forms observed in cultural heritage.

In conclusion, our study underscores the importance of combining traditional analytical techniques with advanced visualization technologies to develop a valuable tool for conservation and restoration strategies, contributing to the long-term preservation of cultural heritage.

From Virtual and Live Access to Prehistoric Rock Art – towards a Rock Art Research Infrastructure in Norway

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This short presentation highlights our efforts to create virtual, digital access to prehistoric rock art and establish a Norwegian Rock Art Research Infrastructure. Our aim is to advance both scientific and humanistic approaches within this field. We will address the technical and contextual challenges we face, including capturing the 3D, 4D, and even 5D aspects of the images, the societies behind the rock art, and the associated archaeological material culture that can be connected with the rock art. We will also outline our goals for the infrastructure, focusing on acquiring new knowledge and creating a comparative analytical tool for rock art research. The idea is further to equip this research tool with proper measures that can assist and be applicable in the process of understanding past images, their meanings, and even help to decode the iconography, thus filling gaps within rock art research. In the context of this seminar, we are particularly eager to receive input on visualization techniques and related measures to fulfill our ambitions.

Alternative scanning geometries and visualization using the FleXCT system and the ASTRA toolbox

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The most common scanning technique to obtain a 3D representation of the internal structure of an object using X-rays is based on a relative rotation of the object and the X-ray beam. This approach to data sampling allows to record a complete set of projections suitable for (analytic) image reconstruction and subsequent visualization. However, situations can arise where this conventional scanning technique is not feasible due to scale limitations of the object or the scanner cavity. This talk aims at presenting alternative scanning geometries, based on relative object rotation and/or translation for such cases. We demonstrate how such scans can be carried out using the FleXCT system, part of the DynXLab core facility of the University of Antwerp, by exploiting the high number of degrees of freedom of the scanning system. The majority of these geometries provide incomplete datasets, to which standard analytical reconstruction does not apply. We circumvent this by employing iterative reconstruction algorithms that take into account the non-conventional scanning geometry using the ASTRA toolbox. Since these scanning geometries do not supply complete datasets, conventional visualization does not apply either, as no full 3D representation is obtained in image reconstruction. We therefore show how the combination of acquisition, image reconstruction and visualization can provide useful information when full rotational CT is not applicable.

X-ray microCT for heritage science

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Since microCT started to spread in the 90's, X-ray computed tomography has been used for heritage science as a non destructive (or almost) instrument to explore archeologic pieces. And even before that, using medical CT scanners for momies for instance. Todays' tools allow a fantastic range of application in this field, from submicron analysis to massive digitalization of collections. Let's explain these possibilities with some technical insight.We will answer in this talk to the question : what are the possibilities and limitations of lab microCT for heritage science?

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