



# Introduction to the Acta IMEKO Thematic Issue '2025 IMEKO TC26 International Conference on Metrology for Archaeology and Cultural Heritage'

Fabio Leccese<sup>1</sup>

<sup>1</sup> Science Department, Università degli Studi Roma Tre, via della Vasca Navale n.84, 00146 Rome, Italy

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## Section: EDITORIAL

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**Corresponding author:** Fabio Leccese, e-mail: [fabio.leccese@uniroma3.it](mailto:fabio.leccese@uniroma3.it)

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Dear Readers,

This Thematic Issue collects the extended version of some of the contributions presented at the 2025 IMEKO TC-26 International Conference on Metrology for Archaeology and Cultural Heritage, held in Bergamo (Italy) from the 15th to the 27th of October 2025. This international conference brought together experts with different expertise but united by the interest in the characterization and conservation of Cultural Heritage (CH). This was the first edition to be held under the auspices of the IMEKO Technical Committee 26 (TC26) chaired by Prof. Fabio Leccese of Università degli Studi Roma Tre [1].

The Conference provided a forum for the exchange of knowledge, ideas, and recent advances in archaeometry, fostering collaboration among specialists from a broad range of disciplines, including archaeologists, conservators, restorers, chemists, physicists, and engineers. Reflecting the inherently interdisciplinary nature of Cultural Heritage (CH), participants discussed a wide variety of topics, with particular emphasis on key metrological challenges and their implications for the study, conservation, and protection of cultural heritage.

The event was specifically designed to encourage interaction and interdisciplinary cooperation among researchers from different scientific backgrounds, while providing an opportunity to present and discuss the latest developments in measurement methods and technologies applied to cultural heritage. MetroArchaeo 2025 also served as a valuable platform for dialogue between the research community and professionals working in public institutions—including museums, galleries, libraries, and archives—as well as representatives of small and medium-sized enterprises. Following the successful example of the Special Issue organized for MetroArchaeo 2023 [2], [3], in this special issue, we present original and high-quality research

papers dedicated to the knowledge of materials and promoting emerging methodologies, applications, and technological solutions for measurements, in the field of CH. In the following, the published papers will be individually presented.

Leccisi *et al.* proposes in [4] the development of a low-cost, easy-to-install, scalable, and highly integrable system, suitable for real and extensive applications for dust detection in museum environments. To detect particles, the Raspberry Pi uses a high-definition camera module on which dust naturally settles. After the acquisition of the image, the platform elaborates directly the images, recognizing and clustering the particles using a self-made recognition software. Although the system has to be still refined, it already shows some advantages if compared to the traditional air quality monitoring approaches. In fact, the proposed system offers a balance between cost, scalability, and information provided, making it a practical tool for safeguarding the preservation of objects.

In [5], Satta *et al.* show an interesting historical instrument replication experiment. The manuscript presents a replication of Galileo's inclined-plane experiment using modern instrumentation and compares it with the historical acoustic-based procedure attributed to Galileo, in which bells placed at regular distances along the inclined plane were activated by the passage of the sliding body. The study not only replicates the measurements of distance and motion described in Galileo's manuscripts, but also emphasizes the central role of time measurement in the formulation of the laws governing uniformly accelerated motion. The experiment is first reproduced using historically plausible instruments, including a reconstructed water clock, in order to assess the feasibility and precision of time measurements available in the seventeenth century. In addition, a comparative analysis is performed using an electronic timing system based on LED–phototransistor pairs has been developed

to acquire transit times with millisecond resolution. The comparison between historical and modern methods allows a quantitative evaluation of measurement uncertainty, and highlights the metrological limitations and capabilities of early experimental practices, while offering a contemporary verification of Galileo's law of motion. The obtained results demonstrated that even with simple experimental setups, when properly characterized from a metrological perspective, allow for a quantitative verification of the fundamental laws of kinematics.

In work [6], Capriotti *et al.* explores the application of artificial intelligence (AI) techniques for the classification of Levantine ceramic thin sections based on their petrographic fabrics. They applied two deep learning architectures, convolutional neural networks (CNNs) and vision transformers (ViTs), to a large and heterogeneous dataset of ceramic thin-section micrographs dating from the Uruk period through the Bronze and Iron Ages. The results obtained through a model performance evaluated used macro-, micro-, and weighted-F1 scores demonstrated high classification performance, reached an accuracy of 88.44% for ResNet18 and 90.52% for DeiT-small. Visual explanations further indicate that the models rely on mineralogical and textural features consistent with petrographic criteria used by human experts, supporting the archaeological interpretability of the proposed approach.

The research of Caridi *et al.* in [7] investigates the radon exhalation rate, natural radionuclide content, and associated radiological hazard to human health linked to Viterbo (city located in the central area of Italy 80 km far from the capital Rome) tuff stone, a material of notable historical and architectural relevance. Particular attention was given to radon exhalation behavior by examining both untreated and accelerated aged (through a salt crystallization test) samples. Radon exhalation rates were quantified using the Closed Chamber Method (CCM) in combination with a DurrIDGE RAD7 real-time continuous radon detector. The measured exhalation rates were subsequently employed in the Markkanen room model to estimate potential indoor radon concentrations while, those of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  were determined by means of high-purity germanium (HPGe) gamma-ray spectrometry. An evaluation of radiological hazard has been done using several indices, including the absorbed gamma dose rate (D), the annual effective dose equivalent (AEDE), the activity concentration index (I) and the alpha index ( $I_\alpha$ ). The results indicated that the measured radionuclide activity concentrations exceed global average values, with the AEDE surpassing the public exposure limit of  $1 \text{ mSv y}^{-1}$  established by Italian regulations. The activity concentration index was also above the recommended threshold, while the alpha index remained below the safety limit, then suggesting a limited contribution of indoor radon exposure. Therefore, the study suggests that new studies are necessary to then support decision-making processes linked to the mitigation of the problems that radiological risks could produce.

Paladini *et al.* show in [8] an in-situ multi-technique study combining Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS) and  $\mu$ -Raman spectroscopy for the molecular characterization of five mortar areas from the theatre of Tindari (Sicily, Italy). The specimens include three ancient mortars attributed to the Roman transformation phase of the monument and two modern conglomerate- and cement-based materials employed in restoration works. DRIFTS spectra

provided information averaged over the superficial portion investigated, whereas  $\mu$ -Raman spectroscopy allowed the analysis of individual grains and localized phases. The analyses revealed clear compositional differences among the investigated mortars among the analyzed areas, mainly involving quartz-, calcite-, clay-rich and cement-related phases, together with Raman markers of biological colonization in one ancient mortar deriving from carotenoid (beta-carotene)-containing biological colonization. The comparison between DRIFTS and  $\mu$ -Raman data highlights demonstrates the complementarity of the two techniques for rapid in situ screening of heterogeneous historical mortars: DRIFTS averages the signal over a larger superficial area, while  $\mu$ -Raman provides localized information on individual grains, minor phases and biological colonization. In particular, the analysis shown how DRIFTS rapidly characterizes the overall molecular composition, whereas  $\mu$ -Raman resolves individual mineral constituents and localized alteration products.

Starting from the Norman bell tower of Salerno Cathedral as a case study, in [9], Barone *et al.* formulate and assess a measurement-model workflow for physical metrology applied to architectural heritage. The spectral components of the 13th-century bell were identified through individually calibrated acoustic measurements, while a finite-element model provided the reference modal frequencies of the belfry-cell air volume.

The comparison between the two datasets was performed by assessing perceptual frequency proximity through the Equivalent Rectangular Bandwidth, together with constrained harmonic relationships quantified in cents. A Monte Carlo-based null model was subsequently applied to evaluate whether the observed level of correspondence could be distinguished from that expected from random spectral matching. The robustness of the results was further examined through sensitivity analyses accounting for both radiating-aperture conditions and temperature-induced changes in the speed of sound. While the adoption of an open-boundary model resulted in mode-specific frequency shifts, energy leakage, and a redistribution of the modal structure, these variations had no substantial impact on the overall interpretation of the results. More broadly, the proposed approach establishes a transparent and reproducible metrological framework that connects experimentally measured quantities with model-based estimates, relevant influence factors, and statistical decision rules, thereby providing a transferable methodology for exploring sonic functions at the intersection of the tangible and intangible dimensions of architectural heritage.

In paper [10], Barone *et al.* propose a measurement-based methodology for the assessment of cultural heritage structures that combines Dynamic Finite Element Modelling (DFEM) with displacement-based vibroacoustic monitoring. The Roman bridge crossing the Savuto River in Calabria, southern Italy, dating back to the 2<sup>nd</sup> century BC and located along the ancient Via Popilia, was selected as the case study. Broadband mechanical seismometers were used to record both translational and rotational displacements induced by ambient excitation, providing information on the modal characteristics of the structure, temperature-related deformation cycles, and local dynamic irregularities. Experimental observations were then compared with the numerical results, showing close correspondence for the principal vibration modes. Conversely, systematic differences in the low-frequency range suggested that the structural configuration cannot be fully represented by

considering only the presently visible geometry. The findings are consistent with the possible presence of a hidden structural component beneath the riverbed and also highlight an asymmetric dynamic response related to restoration works carried out during the twentieth century. Overall, the proposed methodology demonstrates the potential of high-sensitivity displacement measurements to complement and refine digital structural models, allowing measured dynamic behaviour to provide quantitative metrological evidence for both structural assessment and the interpretation of built heritage.

I hope you will enjoy your reading.

Fabio Leccese  
Section Editor

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