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Introductory notes for the Acta IMEKO first issue in 2025

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Dear Readers,

This issue includes papers of the general track that once again highlight the transversality of metrology and how it supports many different investigation fields, the achievement of the United Nations Sustainable Development Goals, and the preservation of the cultural heritange.

The study in [1] focuses on an angel marble sculpture, placed on the central portal of the Gesù Nuovo church in Naples (Italy). The non-destructive and non-invasive optical techniques used were Active Thermography (AT), Colorimetry and 3D scanning. In the paper, the Authors present measurements carried out before and after the restoration of the marble sculpture, consisting in the consolidation of some disintegrated areas and in the removal of both black crusts and biodeteriogens, present in various areas of the sculpture. AT images provided a map of the structural inhomogeneities of the investigated areas, measuring the thermal response. 3D scanning, on the other hand, provided a 3D model of the entire sculpture and measured on a millimetre scale any structural variations due to the restoration. Lastly, colorimetry allowed a quantitative measurement relating to the colour variation of the surface of the sculpture due the cleaning process. All this information was collected and entered into the HBIM (Heritage Building Information Modelling) system, which allowed a systematic cataloguing, providing a complete database on the made measurements.

In [2] an innovative method for the digital representation of ancient books is proposed. Specifically, this approach consists of the reconstruction of the book three-dimensional geometry through photogrammetric images obtained from different viewpoints using Structure from Motion. In addition, both reflectograms in the mid-wave infrared spectral range and thermograms, recorded by pulse thermography, have been adopted since they enable a depth-resolved characterization of the manuscript. The final result is a 4D digital model of the codex, which allows both the visualization of the geometry of the book and stratigraphic exploration of the features buried beneath the surface. Data obtained from humanistic studies and diagnostic surveys have been also mapped onto this model in the form of semantic annotations. Finally, several outputs were developed, including a 3DWeb platform and a holographic showcase designed for museums, with the goal of creating an interdisciplinary experience with the ancient codex.

Measuring emissivity is pivotal for obtaining reliable high-temperature measurements through non-contact techniques such as pyrometry and thermal imaging. The interest in characterizing materials in terms of their radiant properties has increased in recent years due to the expanded application fields of these techniques, ranging from the process industry to aerospace and the energy industry. Various methods are available in the literature to assess material emissivity, but they are primarily classified into indirect and direct methods. The review presented in [3] also addresses different types of materials, various experimental conditions (e.g., heating technologies and measurement frequency bands), and different types of measurement outputs. The aim of this review paper is therefore to systematically examine the literature available on the topic, highlighting the pros and cons of the different methodologies used for measuring emissivity at temperatures up to 2500 °C.

The electrodynamic inertial exciter is an electromechanical transducer extensively implemented in a number of technical applications. The exciter commonly operates in a wide frequency range and its performance strongly depends on the input excitation parameters and output loading. The identification of basic transducer parameters is thus necessary for the design and development of electromechanical devices or for modelling and simulation of exciter frequency response using a lumped-element model. The research presented in [4] introduces an experimental and calculation method for electrodynamic exciter parameters estimation based on the circle-fit of measured frequency response functions, an approach common in a classic experimental modal analysis. The method is suitable for simple

electromechanical or electroacoustic systems whose natural frequency falls within the operational frequency range. The procedure was verified by Authors on displacement to current and voltage to current transfer functions measured on a commercial electrodynamic exciter.

The invention of hand-held X-ray fluorescence devices (HH-XRF) has revolutionized the way ancient materials are analysed. These devices are equipped with highly miniaturized hardware and advanced software, which encourages users to consider them as black boxes. This enables archaeologists, art historians, and restorers to be self-sufficient in performing materials analysis. However, there are specific situations, such as the investigation of copper-based artefacts, where users need to have a deeper understanding of the device's functioning. The article in [5] discusses the experiments carried out to reconfigure a hand-held Bruker Tracer 5g from scratch, compare it with an in-house developed portable spectrometer, and prepare both devices for field use. The Authors focus on optimizing the primary filters and calibrating the devices by considering two quantitative parameters: the limit of quantification and the relative uncertainty of quantification.

The study presented in [6] investigates the impact of gas extraction on soil subsidence at the Shurtan Mining Complex in southern Uzbekistan, utilizing GNSS data. The complex, situated in the Beshkent trough within the Amu Darya Basin, represents a significant hub for hydrocarbon reserves, including gas, and gas condensate. Results indicate a correlation between gas extraction intensity and soil subsidence, with significant settlement observed at specific points most affected by extraction activities. Notably, annual height changes range from -0.5 mm/year to -3.4 mm/year, demonstrating the pronounced impact of gas extraction on subsidence. Tectonic processes, particularly pronounced at the transition boundary from the Tien Shan orogeny to the plain territory (Turan Plate), exert even greater influence on the nature of subsidence. Interpolation techniques, specifically Spline interpolation, are employed to visualize the spatial distribution and dynamics of terrain deformation. Key conclusions emphasize the correlation between gas extraction intensity and soil subsidence, alongside the influence of tectonic processes on height changes. Given the strategic importance of the Shurtan Mining Complex for Uzbekistan's economy, these findings hold significant implications for sustainable resource management and future research endeavours. This GNSS-based investigation offers valuable insights for advancing the understanding of geodynamic processes and informing resource management strategies in similar geological contexts.

Modelling the life cycle of terrestrial arthropods at multiple trophic levels and their interactions with the surrounding environment helps in understanding the evolution of the populations living in the different ecological niches. The need to predict the future scenarii in a precision agriculture and forestry framework is pushing even more the development of models that can support and be supported by measurements. Although the theoretical developments of the last decades provided interesting solutions, the growth in terms of biomass has still not been properly included in physiologically-based models. Modelling the biomass component of insect populations is of wide importance, given the growing availability of measurement systems that provide the biomass reduction in agriculture and forest environments. In [7], the Authors propose a novel physiologically-based model describing populations of terrestrial arthropods considering time, physiological age, and biomass as independent variables. The theoretical formulation led to a partial differential equation describing the population dynamics which includes, as "rate functions", a series of sub-models that can be developed independently. These sub-models relate a specific aspect of the development of arthropods, mostly depending on the species, with the external environment and with the food resources available. A potential application to the case of the corn leafhopper Dalbulus maidis was considered as a secondary step of this study, to explore the model behaviour.

The main goal of the study described in [8], carried out by the ICT Laboratory of ENEA, has been to define a cognitive method of a drawing based on the Photogrammetry technique, applied with success on the Bernini's sanguine well known as Tondo Bernini. Crossing digitalized data with archival data, the method proved to be useful both to improve the knowledge of the artwork, and to define its conservation actual status, since it facilitates the medium and long-term monitoring of the damages that have been measured. With very easy to find and use instruments, such as a photo-camera and commercial software, images of the Tondo have been collected and then post-processed to create a three-dimensional virtual model: a tool that helps in fulfilling different goals with different audience. First, the method applied supports restorers in the conservation practices, allowing them to see what is not evident to the naked eye, especially the smallest cracks on the surface. In parallel, the historians can analyse more in-depth the details highlighted by the 3D model, in order to show up further historical, material, and iconographic characteristics. Finally, it can foster a wider and deeper fruition by the public.

The study in [9] focuses on the importance of slow-growing native Italian poultry breeds, specifically the Bianca di Saluzzo, in biodiversity conservation and local product valorisation, highlighting the need for rapid, precise, and reliable measurements to ensure accurate breed evaluation and support sustainable breeding practices. These breeds, raised through traditional methods with attention to animal welfare, contribute to cultural and gastronomic identity while promoting sustainability. Accurate measurement of meat quality parameters like protein content is crucial for maintaining consumer trust and meeting food regulations. The research compares two protein determination methods: the traditional Kjeldahl method (Kj.m.) and the Near-Infrared Spectroscopy (NIRS). While the Kj.m. is accurate but labour-intensive and hazardous, NIRS offers a faster, non-destructive alternative. The study in [9] involved 192 Bianca di Saluzzo chickens, with protein content in breast meat analysed using both methods. Results showed a statistically significant difference between the methods, with NIRS slightly underestimating protein content compared to Kj.m. Despite this, NIRS demonstrated acceptable accuracy and significant advantages in speed and safety. The study suggests further calibration and refinement of NIRS to improve its precision for poultry meat from slow-growing chickens. Integrating NIRS technology can enhance farm efficiency, sustainability, and biodiversity conservation, providing reliable data on meat quality and nutritional composition. This technological advancement supports small farmers and improves consumer confidence in local poultry products.

To analyse the metrological characteristics of measuring instruments, in [10] it was proposed to expand the conversion equation into a Taylor series. The components of this series yield equations that describe the instrument's sensitivity as well as its additive and multiplicative errors. Additionally, a mathematical model is introduced, allowing the conversion of these additive and multiplicative errors into measurement uncertainty. The

proposed models were tested using a measurement model for ion concentration based on ion-selective electrodes. The measurement accuracy assessment methodology demonstrated that the expanded uncertainty of ion concentration measurements ranges from ± 0.101 pX to ± 0.204 pX, depending on the measurement range. Measurements performed at the beginning of the measurement range exhibit lower values of expanded uncertainty, while measurements conducted at the upper measurement range show slightly higher values of expanded uncertainty.

The study in [11] presents the development of quality control materials (QCMs) for monitoring carbon monoxide (CO) concentrations using a validated gas chromatography-thermal conductivity detector (GC-TCD) method. The QCMs were prepared gravimetrically according to ISO 6142, using a three-step dilution process from pure CO and nitrogen. The resulting QCMs have a target amount fraction of 1000 µmol/mol (ppm). To assess homogeneity, the QCMs were analysed using a validated GC-TCD system calibrated with certified reference materials (CRMs). One-way analysis of variances (ANOVA) revealed excellent homogeneity among the QCMs. Stability was evaluated based on previous studies of similar CO/N_2 mixtures demonstrating long-term stability. Characterization of the QCMs by GC-TCD confirmed an amount fraction of 1004.65 µmol/mol, which was found in good compatibility with the gravimetric value. A quality control chart with upper and lower control limits was implemented for five months, validating the successful preparation of the QCMs. The research in [11] offers a reliable approach for laboratories to develop in-house QCMs for CO measurements, ensuring the accuracy and traceability of their results to the SI units.

The paper in [12] deals with precision agriculture, which is one of the research fields with the greatest development in recent years. Its target is to reduce the waste by seeking methods that allow fruits and vegetables to be grown in a sustainable way by reducing the environmental impact of fertilizers, pesticides, water leaks and so on. To do that, many agricultural companies experiment specific scientific optical techniques as spectroscopy or fluorescence measurements. This allows to collect interesting data on the health status of a plant or fruit/vegetable. In spectrophotometry, the use of LEDs has the advantage of using a light source at a certain wavelength which corresponds to the colour of the light emitted and this can have various experimental advantages, which allow for rapid diagnostic analysis of the target without carrying out invasive measurements.

I hope you will enjoy your reading.

Francesco Lamonaca
Editor in Chief

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