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Introductory notes for the Acta IMEKO third issue in 2025

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Dear Readers,

The third Acta IMEKO issue of 2025 is online. As EiC, it is my pleasure to introduce the papers belonging to the general track.

Ensuring the durability of civil buildings is critical for preventing long-term structural failure. Traditional damage assessment methods, based on visual inspections, are labour-intensive and subjective. The adoption of digital platforms emerges as a solution for complete monitoring of a building during its life cycle. The study in [1], carried out as part of the European *BIM2TWIN* project, focuses on the monitoring of concrete surface quality using vision techniques and deep learning algorithms. Four neural network models are employed for cracks, honeycombing, pitting, and exposed bars, collectively analysing the images to identify and quantify defects. Project managers can assess the criticality of defects based on accurate pixel counts and geometric features, converting measurements from pixels to millimetres. Data are then stored in the digital platform, providing a historical record for future reference and decision-making by project managers.

The paper in [1] deals with SDG 9 – Industry, Innovation and Infrastructure, since it improves infrastructure resilience by using AI and digital monitoring for structural health, preventing failures and ensuring sustainable urban development.

Extensive livestock production on rangelands involves continuous biomass extraction, as various plant species serve as food for different animal populations. Unlike agricultural systems, rangeland biomass extraction reduces plant size without their complete removal, leading to more complicated management strategies. Mathematical models could predict where plant biomass is available, to relocate animals accordingly, but the current state of the art offers plant population models with a single variable, confusing growth rate, fitness, and carrying capacity. The study in [2] addresses this limitation through a model that divides plant populations into two state variables: i) total biomass (B) and ii) the number of individuals/vegetation cover (N). Biomass follows a standard logistic population dynamic constrained by the carrying capacity of the ecosystem, while N represents population spread and resource acquisition. The model integrates Schaeffer and Noy-Meir logistic population models with biomass extraction, and includes a seeding term (S) to account for human interventions. Results showed that system stability and equilibrium depend on the efficiency parameter (N_{h}), which links B and N. Higher N values reduced the system's maximum yield under biomass extraction, highlighting the trade-off between vegetation cover and biomass productivity. This model provides a promising alternative for describing rangeland dynamics under extensive livestock production.

The paper in [2] deals with SDG 15 – Life on Land, since it supports sustainable land management by modelling biomass dynamics, helping balance grazing and ecosystem preservation.

The research presented in [3] evaluates the influence of site conditions (altitude, slope, and exposure) on air temperature, relative humidity (RH), and vapor pressure deficit (VPD) across two distinct sites and four locations within these. Weather station registers were compared with regional estimates from the ERA5 global model. At two locations in one of these sites, microsite conditions were further analysed under varying thinning intensities, using thermohygrometers. To explore daily cycles, a 24-hour band-pass filter using a Gabor wavelet was applied, calculating weighted averages, amplitudes, and phase shifts. Confidence intervals were derived through Monte Carlo simulations to facilitate robust comparisons across treatments and locations. Observations from weather stations revealed significant discrepancies with ERA5 model estimates, highlighting the limitations of the ERA5 model in capturing fine-scale microclimatic variability driven by local topography and vegetation cover. In south-facing slopes, intensive thinning increased air temperature by 2.5 °C and decreased RH by 12 %, resulting in a midday VPD increase of 0.3 kPa. On north-facing slopes, these effects were less pronounced, with air temperature increases of 1.8 °C and RH decreases of 8 %. Thinning effects were amplified in steeper areas and during summer months. Daily cycle analyses revealed that thinning treatments not only increased amplitude, but also caused phase shifts in air temperature and RH, particularly in open areas. These findings underscore the importance of integrating local topographic features, thinning-induced microclimatic changes, and the limitations of ERA5 data into adaptive management frameworks.

The paper in [3] deals with SDG 13 – Climate Action, since it links local forest management to climate adaptation strategies, showing how thinning affects microclimates and ecosystem resilience.

Early detection of brain cancer is crucial for improving treatment outcomes and patient survival rates. The study in [4] proposes a set of algorithms for clustering, classification, and selection of informative features that can aid in the early diagnosis of brain tumours. In collaboration with medical experts, a dataset comprising 218 patient records and 82 clinical and symptomatic features was constructed. Through clustering analysis, the dataset was grouped into four diagnostic classes: (1) Anaplastic astrocytoma in the right frontal region, (2) Adenoma in the chiasmal-sellar region, (3) Glioblastoma in the right frontal lobe, and (4) Meningioma in the right frontal lobe. A feature selection algorithm was then applied to identify the most diagnostically relevant attributes. From the initial 82 features, 19 were determined to be strongly indicative of the disease classes. Further refinement using the proposed algorithm resulted in a subset of six highly informative features, which successfully differentiated the classes with a minimum object similarity threshold of 65 %. The approach demonstrates the potential of data-driven techniques in enhancing the accuracy and efficiency of brain cancer diagnostics, offering a scalable method that could be integrated into clinical decision-support systems.

The paper in [4] deals with SDG 3 – Good Health and Well-being, since it enhances early diagnosis through AI-based clustering and classification, improving patient outcomes and survival rates.

Surface roughness is one of the critical technical requirements of precision machining engineering. Traditional assessment methods, such as standard sample comparisons or contact roughness measurement devices, have long been recognised as having limitations. The case of the study presented in [5] is in the context of machining workshops equipped with computer numerical control systems (CNC), where turning and milling methods account for an average of 60 % of the machining process. Based on convolutional neural networks and image processing techniques, the study proposes a method and a hardware structure to support non-contact roughness grade evaluation through surface texture images. The device is suitable for medium- and small-sized machine parts, meeting the practical production context of CNC machining workshops and the ISO 1302:1992 roughness grade classification standard. The training data were generated from images of surfaces with known roughness levels within the Ra 0.4–3.2 μm. The model achieved an average accuracy of 85.83 %, indicating the feasibility of applying convolutional neural networks and image processing to determine and assess the quality of machined surfaces.

The paper in [5] deals with SDG 9 – Industry, Innovation and Infrastructure, since it advances manufacturing quality control through automated, non-contact inspection methods, boosting efficiency and precision.

The paper in [6] explores the challenges of integrating existing In-Vehicle Networks (IVNs) with Ethernet, explicitly focusing on the coexistence of traditional Controller Area Network (CAN) systems with Single-Pair Ethernet (SPE) and Time-Sensitive Networking (TSN). The research presents an experimental setup using real hardware to simulate a zonal vehicle architecture, where CAN nodes are integrated into the in-vehicle Ethernet network. The approach utilises a gateway implemented on a TSN-enabled switch, facilitating seamless connectivity between the real-time CAN network and the TSN-enabled in-vehicle Ethernet. The study demonstrates the feasibility of combining real-time CAN traffic with high-bandwidth Ethernet traffic through the integrated gateway. It also emphasises the crucial role of TSN features in maintaining the real-time properties of the CAN network, even in the presence of additional traffic loads.

The paper in [6] deals with SDG 9 – Industry, Innovation and Infrastructure, since it enables safer, smarter vehicles through seamless integration of in-vehicle networks, supporting the transition to connected mobility.

Robotic positioning is a cornerstone of high-precision automation, yet conventional techniques often struggle with environmental variability, sensor drift, and dynamic real-time demands. The review presented in [7] critically examines the evolving integration of Artificial Intelligence (AI) and metrology in robotic positioning measurement systems. It identifies the limitations of traditional sensor modalities, including optical encoders, inertial units, LiDAR, and GPS, while emphasising the importance of metrology in achieving traceable accuracy and compliance with standards. The paper in [7] focuses on systems that integrate physics-based metrology with AI-driven algorithms to enable dynamic calibration, traceability, and autonomous error correction. Key AI advancements, such as deep learning for vision localisation, reinforcement learning for dynamic control, and sensor fusion for adaptive error mitigation, are highlighted. These hybrid systems synergise deterministic precision with learning-based adaptability, offering a promising future for robotic accuracy. Key performance benchmarks, error metrics (e.g., RMSE, MAE), and international standards (ISO 9283, ISO 10360) are analysed to assess real-world applicability. Finally, the study identifies emerging trends, such as blockchain-enabled traceability, Explainable AI (XAI), and quantum-enhanced inference. The convergence of AI and metrology is shown to redefine robotic positioning, advancing toward self-calibrating, regulation-compliant systems with high accuracy and resilience.

The paper in [7] deals with SDG 9 – Industry, Innovation and Infrastructure, since it promotes high-precision automation and standard-compliant robotics, supporting smart manufacturing and Industry 4.0.

The study in [8] investigates the impact of data augmentation techniques on the accuracy and prediction probability of deep learning-based terrain classification systems for Unmanned Ground Vehicles (UGVs) in unstructured environments. The challenge of limited datasets in such environments is addressed through the implementation and evaluation of various data augmentation methods, to enhance the accuracy and reliability of pixel-level terrain measurements. The methodology is based on the DeepLabv3+ neural network architecture for supervised learning, trained on a custom dataset collected from an outdoor environment. A systematic assessment of multiple augmentation strategies is conducted, including geometric transformations (cropping and mirroring), colour space modifications (HSV transformations), and noise injection (Gaussian noise addition). The performance of these techniques is quantified using standard metrics, such as classification accuracy and Intersection over

Union (IoU), alongside an analysis of pixel-wise classification prediction probability. Results indicate that, while traditional metrics show modest improvements, the application of data augmentation significantly enhances the model's prediction probability in its measurements, particularly for critical terrain features, such as traversable paths. A detailed analysis of the prediction probability distribution is presented, showing a significant improvement in the model's confidence for correctly classified pixels. Specifically, when augmentation strategies are applied, the percentage of traversable terrain pixels classified with high confidence (> 99.7 % probability) significantly increased from 75 % to 85 %.

The paper in [8] deals with SDG 11 – Sustainable Cities and Communities, since it improves autonomous navigation in unstructured environments, enabling safer and more efficient unmanned ground vehicle operations.

The study in [9] investigates the effectiveness of Global Navigation Satellite System (GNSS) signals for measuring vertical displacement (or heave) in dry conditions, using a controlled pendulum to create a wave-like motion. The experiment was conducted using three GNSS receivers operating in different measurement modes: Single Point (SP), Differential GNSS (DGNSS), and Real Time Kinematics (RTK). An Inertial Navigation System (INS), with high precision for navigation applications, was previously verified, then used as a reference in the experiment. The vertical motion, or heave, was obtained from the three receivers, considering the position measurements or by integrating the velocity measurements over time. Results indicate that GNSS velocity measurements are effective, but precision is limited by sensor characteristics. The RTK mode provided the highest accuracy, with a deviation of 2.5 % from the reference signal, followed by DGNSS at 3.5 %, and SP mode at 4 %. Altitude-based heave estimations showed similar trends, with RTK being the most accurate. However, signal loss in the RTK mode poses challenges in the management of measurement data, impacting measurement stability. The findings suggest that, while GNSS-based heave estimation is feasible, improvements in velocity precision and correction signal reliability are necessary for enhanced accuracy. The study in [9] provides insights into GNSS-based motion measurement techniques, highlighting their potential and limitations in marine applications.

The paper in [9] deals with SDG 14 – Life Below Water, since it enhances ocean monitoring by accurately measuring wave motion, contributing to marine safety and climate-related data collection.

These papers collectively advance the UN Sustainable Development Goals by improving infrastructure durability, sustainable land use, climate adaptation, healthcare diagnostics, and marine monitoring.

They demonstrate how metrology, together with AI-driven methods, enhances accuracy, traceability, and decision-making, ensuring that interventions are efficient and scalable.

Several contributions address Industry 4.0 needs, integrating digital twins, sensor fusion, and autonomous calibration to improve quality and safety. Together, they show that rigorous measurement science is essential for building resilient, sustainable, and innovation-driven societies.

I hope you will enjoy your reading.

Francesco Lamonaca
Editor in Chief

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