ICNDT
2026
Conference

The 1st International Online Conference on Non-Destructive Testing

1–3 July 2026 | Online

Program and Abstract Book

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1–3 July 2026 | Online

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Welcome from the Chair

Dear NDT Community,

On behalf of the Organizing Committee, we are pleased to invite you to participate in the 1st International (Online) Conference on Non-Destructive Testing (ICNDT 2026), which will be held online from **1 to 3 July 2026**.

The theme of this conference is "*NDT for Digital Transformation, Diagnostics, and Preservation*." We aim to bring together leading academic scientists, researchers, and industrial experts to exchange and share their experiences and research results on all aspects of non-destructive testing. It will provide an interdisciplinary platform for presenting and discussing the most recent innovations, trends, and challenges encountered, as well as solutions adopted in the field.

We anticipate stimulating discussions on a range of topics, including, but not limited, to the following:
S1. Digitalization of NDT Data: Exploring advancements in data acquisition, management, and analysis, including big data, cloud computing, and the Internet of Things (IoT) in NDT.
S2. Artificial Intelligence and Machine Learning for NDT: Focusing on the application of AI and ML techniques for automated detection, characterization, and predictive maintenance.
S3. Advanced Sensing Technologies: Covering innovations in NDT sensors, including novel materials, micro- and nano-sensors, and smart sensors.
S4. Robotics and Automation in NDT: Addressing the use of robotic systems and automated solutions for efficient and reliable NDT inspections.
S5. NDT for Structural Health Monitoring: Examining the role of NDT in the continuous monitoring of the integrity of structures and components.
S6. NDT for Additive Manufacturing: Investigating the challenges and solutions of NDT in ensuring the quality of additively manufactured parts.
S7. NDT in Cultural Heritage Preservation: Discussing the application of NDT techniques for the diagnostics and preservation of historical artefacts and monuments.
S8. Data Fusion and Integration: Exploring the synergistic combination of data from diverse NDT techniques and complementary sources to improve the accuracy, reliability, and efficiency of measurements.

We believe that ICNDT 2026 will provide a valuable platform for fostering collaboration and knowledge sharing among researchers and practitioners in the field of non-destructive testing. We look forward to receiving your contributions and welcoming you to the conference.

Dr. Luca Bianchini Ciampoli
Conference Chair
Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University, Italy

Prof. Dr. Andreas Loizos
Conference Chair
Laboratory of Pavement Engineering, National Technical University of Athens (NTUA), Greece

Prof. Dr. Fabio Tosti
Conference Chair
School of Computing and Engineering, University of West London, UK, The Faringdon Research Centre for Non-Destructive Testing

and Remote Sensing,
University of West London,
UK

NDT — **Journal of Non-Destructive Testing** (ISSN 2813-477X) is an international, peer-reviewed open access journal on non-destructive testing science, technology, and their applications. The journal's focus covers three major areas: (i) the collection, processing, modeling, fusion, and interpretation of data to enhance research for standalone non-destructive methods and their applications; (ii) the development of a multisource, multiscale, and multitemporal diagnostics and monitoring resource; (iii) the design and implementation of state-of-the-art technological solutions exploiting new paradigms throughout the use of different physical and working principles of sensing. The journal aims to be a leader in research in the NDT area of science through the dissemination of more inclusive and interdisciplinary theoretical, numerical, and practical scientific contributions. The goal is to enhance the capabilities of conventional and emerging technology in new investigation settings and complex scenarios.

Journal Webpage: https://www.mdpi.com/journal/ndt

Keynote Speakers

Dr. Sakdirat Kaewunren

Birmingham Centre for Railway Research and Education (BCRRE), School of Engineering, University of Birmingham, Birmingham B15 2TT, United Kingdom
Dr Kaewunruen is a reader in railway and civil engineering at the University of Birmingham, UK. He has more than 25 years experience in industry and academia, with over a decade of real-world industry experience, over 600 technical publications and evidence-based consultancy reports, and has served on the editorial boards of many reputable international journals. He was a winner of Europe's Trasport Research Arena Vision Award in 2020, and has been consistently ranked in the World's Top 100 Most Cited Scientists in Civil Engineering by Stanford University & Elsevier. His research is fully transformative and has unlocked the real-world impacts through the standard developments, industry design and maintenance guidelines, policy recommendation, and product innovation. He serves in the MC for EU Cost Actions: CircularB and Eco4All.

Dr. Sina Sareh

RCA Robotics Laboratory, Royal College of Art, London, UK
Dr. Sina Sareh is Academic Leader and Reader in Robotics and Design Intelligence at the Royal College of Art's Robotics Laboratory. His work focuses on robotics for inspection, maintenance, repair, and sustainable industrial operations. He has secured and delivered research projects worth more than £8 million, including leadership of the EPSRC-funded Circular Robot 5.0 programme. His innovations in robotic mobility, autonomous maintenance, and circular manufacturing integrate robotics, AI, and digital technologies to improve industrial resilience, extend asset lifecycles, and reduce environmental impact.

Prof. Dr. Enzo Rizzo

Department of Physics and Earth Sciences, University of Ferrara, Ferrara, Italy
Prof. Enzo Rizzo is Associate Professor at the University of Ferrara specializing in Applied Geophysics methods, particularly on geoelectrical and electromagnetic techniques. With extensive experience in both academic and applied research, he contributes to the advancement of non-invasive geophysical investigations for subsurface characterization in complex and multidisciplinary contexts on engineering, environmental studies, hydrogeology, structural geology and archaeology. He has published over 120 journal articles on international journals and serves on the editorial boards.

Prof. Dr. João Oliveira

CENIMAT/I3N, Department of Materials Science, NOVA School of Science and Technology, Universidade NOVA de Lisboa, Caparica, 2829-516, Portugal
Prof. Oliveria is a full professor of materials science with interest on welding and additive manufacturing of advanced engineering materials.

Dr. Niels Møller Israelsen

Head of OCT and Software, NORBLIS ApS, Building 343, Ørsteds Plads, 2800 Kgs. Lyngby, Denmark. Niels is co-founder of NORBLIS ApS, a spin-out of Technical University of Denmark (DTU). He is leading the mid-infrared OCT laser scanner hardware and software production and development, for space and aerospace, wind energy and defence industries. He obtained his PhD degree in 2015 in quantum optics from DTU, after which he started his career in OCT, developing laser scanners for non-destructive inspection of industry coatings and ceramics. Niels also has a position at DTU Electro as Senior Researcher.

Program at a Glance

Time (CEST)	1 July 2026 Wednesday	2 July 2026 Thursday	3 July 2026 Friday
Morning Session CEST	**Session 1:** Digitalization of NDT Data	**Session 5:** NDT for Structural Health Monitoring	**Session 9:** Early Career Researcher (ECR) Session
Afternoon Session CEST	**Session 3:** Advanced Sensing Technologies **Session 4:** Robotics and Automation in NDT	**Session 2:** Artificial Intelligence and Machine Learning for NDT **Session 7:** NDT in Cultural Heritage Preservation	**Session 6:** NDT for Additive Manufacturing **Session 8:** Data Fusion and Integration

ICNDT 2026 Program

1st July 2026 (Wednesday)

Session 1: Digitalization of NDT Data

Time: 9:00 (CEST, Basel) | 03:00 (EDT, New York) | 15:00 (CST Asia, Beijing)

CEST Time	Speaker	Title
9:00–9:10	*Opening Speech from the chairs* *Prof. Dr. Fabio Tosti* *Prof. Dr. Andreas Loizos* *Dr. Luca Bianchini Ciampoli*	
9:10–9:15	*Welcome from the session chair* *Prof. Dr. Andrea Benedetto*	
9:15–9:30	**Oral Speaker** Kyle Rose	Nondestructive testing digital twin definition
9:30–9:45	**Oral Speaker** Suman K	Simulation Study on Detection of Internal and Surface Defects in Wire Ropes Using Magnetic Flux Leakage
9:45–10:00	**Oral Speaker** Ruogu Tang	A Simulation-Based Non-Destructive Framework for Assessing Polymer Chain Flexibility
10:00–10:15	**Oral Speaker** Delphina Naa Darkoa Darko	Digitalisation and Multi-Modal Integration of NDT and Remote Sensing Data for Coastal Heritage Monitoring: The Reculver Towers Demonstrator
10:15–10:30	**Oral Speaker** Kuldeep Sharma	From Inspection to Prediction: Integrating NDT, RBI, and AI for Industrial Asset Integrity Management
10:30–10:45	**Oral Speaker** Vineet Yadav	Multi-Sector Failure Analytics and Advanced Non-Destructive Evaluation Strategies for Risk-Based Industrial Asset Integrity Management
10:45–14:00	**Break**	

Session 3: Advanced Sensing Technologies
Session 4: Robotics and Automation in NDT

Time: 14:00 (CEST, Basel) | 08:00 (EDT, New York) | 20:00 (CST Asia, Beijing)

CEST Time	Speaker	Title
Session 3: Advanced Sensing Technologies		
14:00–14:05	*Welcome from the session chair* *Dr. Siqi Wang*	
14:05–14:30	**Keynote Speaker** Dr. Niels Møller Israelsen	Zero defect quality by mid-infrared OCT laser scanning.
14:30–14:45	**Oral Speaker** **Esteban Gonzalez Valencia**	Optimization of Bloch-like surface wave sensors via multi-nanostrips on side-polished photonic crystal fibers
14:45–15:00	**Oral Speaker** **Xiaochu Pang**	Defect Evaluation in Ferromagnetic Materials Using a Custom-Designed Instrument for Magnetic Barkhausen Noise and Hysteresis Loop Measurements
15:00–15:15	**R. G. Rejith** Marco Sanna Angotzi	Non-destructive estimation of crop nitrogen using Proximal Hyperspectral Remote Sensing
Session 4: Robotics and Automation in NDT		
15:15–15:20	*Welcome from the session chair* *Prof. Dr. Nicolas P. Avdelidis*	
15:20–15:45	**Keynote Speaker** **Dr. Sina Sareh**	Circularity Robotics: Enabling Sustainable Industrial Futures through Intelligent Automation
15:45–16:00	**Oral Speaker** **Prince Alex Ogbodum**	High-Precision Piezoelectric Sensor Positioning with SMC Control for Robotic NDT in Pipelines
16:00–16:15	**Oral Speaker** **Yunus Çelebi**	Drone-Supported Multi-Risk Inspection Model For Occupational Health and Safety in Confined Areas

2nd July 2026 (Thursday)

Session 5: NDT for Structural Health Monitoring

Time: 9:00 (CEST, Basel) | 03:00 (EDT, New York) | 15:00 (CST Asia, Beijing)

CEST Time	Speaker	Title
9:00–9:05	*Welcome from the session chair* *Dr. Leandro Maio*	
9:05–9:30	**Keynote Speaker** Dr. Sakdirat Kaewunruen	TBC
9:30–9:55	**Keynote Speaker** Prof. Dr. Enzo Rizzo	NDT methods for Monitoring Steel Rebar Corrosion in Reinforced Structure
9:55–10:10	**Oral Speaker** Siqi Wang	Real-Time Monitoring and Visualization for Intelligent Compaction of Asphalt Pavements Based on Ground-Penetrating Radar
10:10–10:25	**Oral Speaker** Amirhossein Askari	Degradation Monitoring of Reinforced Concrete Structures by NDT: laboratory and field applications
10:25–10:40	**Oral Speaker** Ruggero Pinto	FBG thermo-mechanical monitoring of airport rigid pavement infrastructures
10:40–10:55	**Oral Speaker** Saeed Parnow	Advanced Diagnostic of Subsurface Decay in Rigid Airfield Pavements: A Signal-Processing-Enhanced GPR Approach
10:55–11:10	**Oral Speaker** Saeed Sotoudeh	Ground- and Space-Borne Interferometric Radars for Monitoring Cable-Stayed Bridges: A Multi-Scale Monitoring Framework
11:10–11:25	**Oral Speaker** Shekoufeh Abdollahi	Development of a UAV-Mountable Multimodal Radar System with Deep Learning for Structural Health Monitoring
11:25–11:40	**Oral Speaker** Giorgia Sanvitale	Potential of Satellite Remote Sensing for Flexible Pavement Monitoring
11:40–14:00	**Break**	

Session 2: Artificial Intelligence and Machine Learning for NDT
Session 7: NDT in Cultural Heritage Preservation

Time: 14:00 (CEST, Basel) | 08:00 (EDT, New York) | 20:00 (CST Asia, Beijing)

CEST Time	Speaker	Title
Session 7: NDT in Cultural Heritage Preservation		
14:00–14:05	*Welcome from the session chair* *Dr. Francesco Soldovieri*	
14:05–14:20	**Oral Speaker** Saeed Parnow	Advanced GPR Data Interpretation for the Diagnostic of Buried Historical Road Tracks: Case Studies from Ancient Rome
14:20–14:35	**Oral Speaker** Sunil Pradhan	Leveraging machine learning for the automated identification of cultural heritage materials via external reflectance FTIR spectroscopy
14:35–14:50	**Oral Speaker** Muhammad Khubaib	Integrating Non-Destructive Testing with HBIM for the Preservation of Timber-Framed Masonry Heritage Structures in Switzerland
Session 2: Artificial Intelligence and Machine Learning for NDT		
14:50–14:55	*Welcome from the session chair* *Dr. David Daou*	
14:55–15:10	Oral Speaker Otabek Atabeyev	Toward Real-Time FTIR Analysis: A Machine Learning Toolkit for Spectral Classification
15:10–15:25	**Oral Speaker** Maksymilian Kwasnik	Accelerating Analysis of Ultrasonic Test Data in Carbon Fibre Reinforced Polymers with Vision Foundation Models

15:25–15:40	**Oral Speaker** Grigório Ribeiro Soares Neto	A descriptor-based machine learning framework for estimating pavement crack geometry from synthetic GPR hyperbolic responses
15:40–15:55	**Oral Speaker** Cristian Adrian Calistru	Liquid Flow Front Estimation From Ultrasonic Guided Wave Signals Using Machine Learning
15:55–16:10	**Oral Speaker** Marios Giouvanakis	Multi-channel AE scalogram imaging with ML regression for non-invasive refrigerant flow characterization
16:10–16:25	**Oral Speaker** Sunil Pradhan	Edge-deployable PINNs: Physics-guided residual learning for smart manufacturing

3rd July 2026 (Friday)

Session 9: Early Career Researcher Session

Time: 9:00 (CEST, Basel) | 03:00 (EDT, New York) | 15:00 (CST Asia, Beijing)

CEST Time	Speaker	Title
9:00–9:05	*Welcome from the co-chair Dr. Luca Bianchini Ciampoli*	
9:05–9:20	**Oral Speaker** Joel Benjamin Johnson	Sub-molecular Structural Quality Assessment of Australian Faba Bean Using ATR-FTIR
9:20–9:35	**Oral Speaker** Elikem Doe Atsakpo	Digitalising Acoustic Data: An Extended Reality Framework for the Visualisation of Simulated Sound Dispersion in the Ancient Roman Theatre of Palmyra
9:35–9:50	**Oral Speaker** Keiichiro Oshima	Fault Diagnosis of Rotating Machinery using Infrared Stress Method with Deep Learning
9:50–10:05	**Oral Speaker** Yuika Ito	Evaluation of Acoustic Emission Energy Trend in Small-diameter Concrete Core with Large Size Coarse Aggregate under Compression Stress Field
10:05–10:20	**Oral Speaker** Hiromu Tanaka	Finite Element Simulation of Compressive Fracture Behavior for Concrete Core incorporating X-ray CT-Based Material Phase Modeling
10:20–10:35	**Oral Speaker** Francesco Mercogliano	Combining GPR and Magnetic Data through the Integration of Microwave Tomography (MWT) and Depth from EXtreme Points (DEXP)
10:35–10:50	**Oral Speaker** Ujjal Mandal	A Robust Numerical Framework for Ultrasonic Wave Characterization in Complex Petrophysical Environments
10:50–14:00	**Break**	

Session 6: NDT for Additive Manufacturing
Session 8: Data Fusion and Integration

Time: 14:00 (CEST, Basel) | 08:00 (EDT, New York) | 20:00 (CST Asia, Beijing)

CEST Time/CST Asia Time	Speaker	Title
Session 6: NDT for Additive Manufacturing		
14:00–14:05	*Welcome from the session chair Prof. Dr Philip Cox*	
14:05–14:20	**Oral Speaker** Andrea Ehrmann	Birefringent properties of 3D printed and other polymers
14:20–14:35	**Oral Speaker** Andrejs Kovalovs	Non-destructive technique for determining the elastic properties in carbon-reinforced polymer laminates using modal frequencies
14:35–14:50	**Oral Speaker** Stefan Keuler	Influence of Remaining Support Structures on the Ultrasonic Testing of Additively Manufactured Components
14:50–15:15	**Keynote Speaker** Prof. Dr. João Oliveira	TBC
Session 8: Data Fusion and Integration		
15:15–15:20	*Welcome from the session chair Dr. Pietro Tizzani*	
15:45–16:00	**TBC**	TBC
16:00–16:15	**Oral Speaker** Kyle Rose	Using deep learning to enhance eddy current system transfer functions

Session 1. Digitalization of NDT Data

sciforum-165062: A Simulation-Based Non-Destructive Framework for Assessing Polymer Chain Flexibility

Ruogu Tang

Department of Chemistry, University of Massachusetts Lowell, Lowell, Massachusetts, USA, 01854

Non-destructive testing (NDT) increasingly incorporates computational and model-based approaches to enable indirect evaluation of material behavior without physical alteration or damage. In this context, digital and simulation-assisted strategies provide a pathway to infer internal material properties through externally observable responses. In this study, a software-based simulation framework is developed to support non-destructive assessment of polymer chain flexibility and dynamic response under thermal motion and externally applied forces. Polymer chain dynamics are modeled using a stochastic random-walker-based approach combined with molecular motion simulations implemented in the Large-scale Atomic/Molecular Massively Parallel Simulator (LAMMPS), enabling representation of both equilibrium and force-driven behavior at the molecular level.

To establish relevance to NDT, the framework explicitly links internal chain conformation to quantifiable response descriptors that can serve as proxies for measurable signals. Key statistical metrics, including end-to-end distance distributions and mean-square displacement scaling, are extracted to characterize conformational evolution and flexibility under varying conditions. These descriptors provide a predictive basis for interpreting how polymer systems would respond to external probing, thereby enabling indirect inference of material properties without destructive mechanical testing.

Simulation results demonstrate systematic and reproducible changes in polymer chain conformation in response to applied forces, highlighting the sensitivity of the approach to flexibility-related parameters. Overall, this work establishes a simulation-assisted NDT paradigm in which molecular-level modeling supports non-invasive characterization of polymer materials and contributes to the integration of digital methodologies within emerging non-destructive testing frameworks.

sciforum-183540: Digitalisation and Multi-Modal Integration of NDT and Remote Sensing Data for Coastal Heritage Monitoring: The Reculver Towers Demonstrator

Delphina Naa Darkoa Darko[1,2,*], Omar Abdillahi Osman[1,2], Mohammad Kargar[1,2], Moein Motavallizadeh Naeini [1,2], Saeed Parnow [1,2], Malte Ressin [1,2], Tesfaye Tessema [1,2], Ilaria Catapano [3], Sebastiano D'Amico [4], David Daou [5], Atif Mohammed Ghani [6], Alba L'Astorina [3], Neil Linford [7] and Fabio Tosti [1,2]

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2 The Faringdon Research Centre for Non-Destructive Testing and Remote Sensing, University of West London, London, United Kingdom of Great Britain
3 National Research Council of Italy (CNR) - Institute for Electromagnetic Sensing of the Environment (IREA), Naples, Italy
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5 Institute for Environment and Human Security, United Nations University (UNU-EHS), Bonn, Germany
6 Royal College of Art, School of Communication, London, United Kingdom of Great Britain
7 Historic England, Geophysics Team, Portsmouth, United Kingdom of Great Britain

The digitalisation of Non-Destructive Testing (NDT) data is critical for the preservation of heritage assets. This paper presents the technical development of a digital demonstrator for the British Academy-funded project, BLUE-HeArTS (BLUE Heritage through Art, Technology, and Science), which connects scientific monitoring with artistic narratives.

This study focuses on the Reculver Towers in Kent, UK, a heritage site highly vulnerable to coastal erosion. A 3D Unity model was engineered, integrating high-resolution laser scans of the towers with surface-related remote-sensing data such as Normalized Difference Vegetation Index and Land Surface Temperature maps.

Additionally, the model also incorporates topographically corrected Ground-Penetrating Radar (GPR) radargrams to visualise the structural integrity of sea defence areas [1]. By digitalising these datasets, the system allows for a holistic assessment of climate-driven risks [2,3].

Technical viability was evaluated using established geospatial extended reality metrics [4]. This formed the basis for frame-rate profiling and processing unit utilisation across different hardware configurations to measure efficiency while preventing motion sickness [4].

Initial results demonstrate that integrating dense GPR and hyperspectral data offers a novel diagnostic tool, though rendering complexity remains a primary bottleneck, underscoring the need for optimisation in heritage conservation digitisation workflows.

Acknowledgements

The authors would like to acknowledge the project BLUE-HeArTS (January – September 2026), funded by the British Academy under the "Pump Priming Collaboration between UK and EU Partners 2026" programme (Award Reference: PPHE26\100311). This research was supported by the Vice-Chancellor's PhD Scholarship at the University of West London.

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[1] N. Linford, Historic England 2020.
[2] A. Ghani, 2024.
[3] F. Tosti, I. Catapano, A. M. Ghani, D. Daou, S. D'Amico, A. Lastorina, N. Linford, M. Naeini , T. Tessema, 2026.
[4] E. Atsakpo, F. Mercogliano, S. Uzor, P. Saadati, A. Barone, F. Accomando, R. Castaldo, I. Catapano, P. Tizzani , F. Tosti, 2025.

sciforum-183515: From Inspection to Prediction: Integrating NDT, RBI, and AI for Industrial Asset Integrity Management

Kuldeep sharma [1,*], Ashok Kumar [2] and Vineet Yadav [3]

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[2] Welding, Welspun Pipes INC, Little Rock, 72206, USA
[3] Quality Department, Born Inc., Tulsa, 74107, USA

This paper presents an evidence-based review of Non-Destructive Testing (NDT) and its role in ensuring the integrity of high-consequence industrial assets across aerospace structures, overhead cranes, high-pressure systems, and bridge closure joints. Drawing on global safety statistics from organizations such as ILO, BLS, and NBBI, the study highlights the significant human and economic impact of inspection deficiencies and establishes the need for integrated inspection strategies.

Three primary contributions are introduced. First, a unified framework linking NDT method selection with failure-mode capability across multiple asset classes is developed, enabling structured inspection planning. Second, a fully worked quantitative Risk-Based Inspection (RBI) case study, based on API RP 580/581, demonstrates the identification of dominant damage mechanisms and optimized inspection intervals for a refinery pressure vessel. Third, an AI-enabled NDT pipeline is validated using a simulated phased array ultrasonic testing (PAUT) dataset, achieving 92.9% classification accuracy and providing confusion-matrix-based performance insights.

In addition, technical models including Paris law for crack growth, Probability of Detection (POD) characterization, and machine learning performance metrics are integrated to support quantitative inspection program design. The results demonstrate that combining NDT, RBI, and AI enables a transition from periodic inspection toward predictive, risk-informed asset integrity management.

This integrated framework provides a practical pathway for industry adoption of NDT 4.0 and supports data-driven decision-making for enhanced safety, reliability, and cost efficiency.

sciforum-181987: Multi-Modal Data Fusion: A Stakeholder-Centred Extended Reality Framework for the Digitalisation of Geophysical NDT Data

Elikem Doe Atsakpo [1,2,*], Francesco Mercogliano [3,4,5], Stephen Uzor [6], Saeed Parnow [1,2], Atiyeh Ardakanian [1,2], Andrea Barone [3,4,5], Filippo Accomando [3,4,5], Raffaele Castaldo [3,4,5], Ilaria Catapano [3,4,5], Pietro Tizzani [3,4,5] and Fabio Tosti [1,2]

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Integrating multi-modal data is central to the digital transformation in infrastructure health monitoring. Non-destructive testing (NDT) methods such as Ground Penetrating Radar (GPR) and Magnetometry are often combined to predict the presence, depth, and ferrous characteristics of subsurface structures. Despite advancements in NDT data acquisition, processing, and evaluation, interpretation still largely depends on expert judgment or rule-based approaches, which can introduce subjectivity and inconsistencies and limit repeatability.

Although visualisation techniques are improving, many systems still rely on simplified two-dimensional representations, such as radargrams, to portray complex subsurface features, making interpretation difficult. While three-dimensional visualisation methods and immersive extended reality (XR) technologies have been suggested to improve spatial understanding and lessen cognitive load, their adoption in industry remains limited due to challenges with integration and validation.

A recent study identified technical challenges in immersive visualisation, including frame-rate instability and high GPU usage in a VR prototype using GPR and magnetometry data. However, technical performance alone does not determine success; stakeholder perspectives are essential to ensure XR outputs align with the analytical needs and decision-making processes of geophysical professionals. Furthermore, stakeholder-centred development can enhance usability, practicality, and relevance, supporting wider adoption of such technologies.

This study extends the prototype to conduct preliminary user testing with six expert geophysics stakeholders. Thematically analysed feedback, gathered through semi-structured interviews, revealed the following: (1) Dynamic Data Interrogation: the need for interactable colour maps; (2) Interactive Spatial Querying: selecting sectors to access metadata; (3) User-centric Design: ensuring digital outputs match field-expert mental models; and (4) Integrated Data Cataloguing: enabling the selective management and visualisation of multi-sensor datasets.

Acknowledgements: The authors acknowledge the funding support from the University of West London and contributions from ITINERIS, GAIA iLAB, and the Faringdon Research Centre. We also appreciate a visiting scholarly exchange between UWL and CNR-IREA that supported the study.

sciforum-183514: Multi-Sector Failure Analytics and Advanced Non-Destructive Evaluation Strategies for Risk-Based Industrial Asset Integrity Management

Kuldeep sharma [1,*], Vineet Yadav [2] and Ashok Kumar [3]

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This paper presents a comprehensive, evidence-based review of Non-Destructive Testing (NDT) as a core enabler of industrial asset integrity and predictive maintenance. It systematically analyses failure mechanisms across four high-criticality sectors—aircraft structures, overhead cranes, high-pressure systems, and bridge closure joints—linking dominant degradation modes such as fatigue cracking, stress corrosion cracking, creep, and shear failure to appropriate inspection strategies. Using validated global datasets from the International Labour Organization (ILO), Bureau of Labor Statistics (BLS), National Board of Boiler and Pressure Vessel Inspectors (NBBI), and Federal Aviation Administration (FAA), the study quantifies the safety, economic, and operational consequences of inadequate inspection practices. A structured comparative framework evaluates key NDT techniques, including ultrasonic testing, phased array ultrasonics, radiography, eddy current testing, magnetic particle inspection, acoustic emission, and emerging GMR-based sensing, across performance metrics such as sensitivity, inspection depth, and automation potential. The work further integrates Risk-Based Inspection (RBI) principles aligned with API RP 580/581 and introduces a five-stage AI-driven diagnostic pipeline combining signal processing, machine learning, and decision-support systems. Finally, the paper examines digital twin–enabled predictive maintenance as a transformative approach for real-time asset monitoring and lifecycle optimization. The study provides a unified framework connecting failure physics, inspection technology, and intelligent maintenance systems for next-generation industrial reliability engineering.

sciforum-181829: Nondestructive testing digital twin definition

Kyle Rose * and Jiming Song

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A discussion on digital twins in nondestructive testing begins with the history of digital twin technology. Starting as a lifecycle management tool with the name coined by NASA, digital twins quickly grew. Several key factors restrict digital twin technology from being classified as an emerging technology. These factors include radical novelty, definition agreement, and applicable impacts. The path towards enabling digital twin technology to be defined as an emerging technology starts with a comparison of the various definitions of digital twins across industries. The definitions break out into two main schools of thought. The first school of thought is the original lifecycle management tool definition called the Vickers/Grieves digital twin. The second school of thought comes from the National Academies of Sciences, Engineering, and Medicine (NASEM) digital twins which addresses the factors restricting digital twin technology. Differences in the schools of thought and the applicability to nondestructive testing are demonstrated in the comparisons of their respective typology. This comparison establishes that the NASEM school of thought is best suited for digital twin technology to become an emerging technology in nondestructive testing. Further expansion on the NASEM digital twin identifies the importance of verification, validation, and uncertainty quantification (VVUQ). VVUQ is critically important in nondestructive testing digital twins where quantified uncertainty is a normal qualification measure for an inspection. Various common methods of nondestructive testing are presented with application to the typology of NASEM digital twins. This study concludes with a proposed nondestructive testing specific definition based on the formal NASEM definition.

sciforum-186251: Simulation Study on Detection of Internal and Surface Defects in Wire Ropes Using Magnetic Flux Leakage

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This study aims to suggest a methodology which combines Magnetic Flux Leakage (MFL) and Convolutional Neural Networks (CNNs) technologies in order to quantify internal and surface defects in wire ropes. Wire ropes are widely used as a key component in most engineering structures, which makes it necessary to pay attention to their condition as the structural integrity of these components is critical when it comes to safety and performance issues. In fact, classical NDT techniques such as visual and ultrasonic ones often fail when it comes to locating internal defects or providing an accurate quantitative assessment of those already detected. MFL allows detecting changes in magnetic flux caused by defects, but, at the same time, does not allow making a distinction between internal and external defects and cannot accurately measure parameters of defects (e.g., their width, depth, and cross-sectional loss). Thus, MFL is combined with CNNs to provide more efficient and automated inspections. A CNN algorithm, trained on MFL data, should be able to recognize features related to certain defects and provide a precise estimation of defect parameters.The effectiveness of the system is validated through both simulation and experimental data, demonstrating its potential to enhance safety in industries that rely on wire ropes.

Session 2. Artificial Intelligence and Machine Learning for NDT

sciforum-183520: Edge-deployable PINNs: Physics-guided residual learning for smart manufacturing

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Resistance spot welding is central to automotive manufacturing, yet real-time monitoring is often hindered by the rarity of defect samples and the high computational demands of multimodal sensing. This study proposes a lightweight physics-guided residual learning framework designed for high-precision weld classification with the potential for edge-level deployment. Unlike traditional black-box models, this architecture utilizes a dedicated physics branch based on the Joule heating law to establish a baseline, while a residual neural branch captures complex, non-linear anomalies. This hybrid approach enables the model to remain grounded in physical reality. This strategy achieves an overall classification accuracy of 95% and a macro F1-score of 0.82, significantly improving the recall of critical "Explode" defects to 81%. By prioritizing the detection of catastrophic failures while maintaining 98% precision for healthy welds, the model presents a scenario of evaluating safety without compromising industrial throughput. Furthermore, to study its applicability for factory-floor integration, the model was optimized via INT8 quantization, achieving a 3.5x compression ratio with minimal impact on diagnostic integrity. The results demonstrate that embedding the domain-specific physical constraints not only presents a scenario of model reliability in safety-critical applications but also enables the deployment of sophisticated AI diagnostics on low-power industrial edge controllers. Furthermore, the goal is to propose a lightweight model for industrial settings where expensive imaging hardware is unavailable or economically impractical. The model is inherently designed for simplistic deployment in small and medium-scale manufacturing environments, such as monitoring localized spot-welding parameters in Tier-2 automotive component assembly lines. This framework is also applicable to production lines requiring rapid quality control without a major infrastructure overhaul; for instance, it can be deployed onto standard programmable logic controllers in automotive supplier factories or small-scale metal stamping shops.

sciforum-176672: AI-Integrated Hydrogel Wearable Patches for Non-Invasive Skin Cancer Biomarker Detection

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Background: Skin cancer is among the most prevalent malignancies globally. Early detection remains the most crucial component in improving patient outcomes. However, current diagnostic pathways depend on dermoscopy and invasive biopsies. These methods are sometimes costly or distressing for the patients undergoing them. Hydrogel-based wearable patches have emerged as a promising class of biosensors that can interface directly with skin tissue and interstitial fluid to capture disease-related biomarkers including inflammatory cytokines, non-invasively. Despite this potential, the translation of raw signals into clinically meaningful diagnostic outputs remains a challenge. The integration of machine learning with hydrogel biosensor platforms offers a pathway toward automated, non-destructive screening for early-stage skin cancer biomarkers.

Aim: This study aims to propose a machine learning framework using hydrogel-based wearable skin patches for non-invasive detection and characterization of biomarkers associated with skin cancer.

Methods: This study proposes a conceptual framework where a flexible hydrogel patch is applied directly to the skin, enabling continuous sensing of biomarkers including inflammatory cytokines and tumor-associated proteins. The hydrogel matrix is designed to incorporate electrochemical or optical nanosensors. Output data is fed into a machine for automated analysis. Supervised classification models including logistic regression are proposed as baselines. Model performance will be evaluated using standard metrics such as AUC and sensitivity. All detection is performed non-invasively, with no skin disruption, aligning with core non-destructive testing principles.

Expected Results: Integration of hydrogel-based sensing with machine learning will enable accurate and early-stage detection of skin cancer-associated biomarker profiles, outperforming conventional approaches while maintaining a non-invasive detection technique.

Conclusion: This work presents a novel framework for non-invasive skin cancer biomarker detection, combining advanced hydrogel sensing technology with machine learning to support earlier diagnostic screening.

sciforum-181870: Regression-based estimation of fault detection in photovoltaic devices using Machine Learning

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This study explores a regression-based non-destructive testing framework for estimating electrical fault severity in grid-connected photovoltaic (PV) systems using machine learning. The study is based on an open access dataset generated from a 250 kW PV plant modeled in MATLAB/Simulink, including inverter control, distributed string current sensing, and environmental variability. Unlike conventional diagnostic approaches that formulate PV fault detection as a classification problem, the proposed methodology estimates fault resistance as a continuous severity indicator under string fault, string-to-ground fault, and string-to-string fault conditions. The input space includes non-invasive electrical and environmental descriptors, namely distributed string currents, total plant current, DC voltage, DC power, irradiance, temperature, and engineered range-based features extracted from inter-sensor current deviations. The three supervised regression models implemented and compared are Random Forest, XGBoost, and an Artificial Neural Network. The methodological workflow includes data preprocessing, feature engineering, training and testing partitioning, hyperparameter tuning, and model evaluation using R^2, RMSE, MAE, and residual trend analysis. The results indicate that the regression-based formulation can capture the relationship between electrical variables and fault-related operating conditions. Among the evaluated models, Random Forest achieved the best predictive performance, obtaining an R^2 of 0.898 on the test set, which suggests a strong capacity to estimate the proposed continuous fault indicator. XGBoost also showed competitive performance, reaching an R^2 of 0.835, confirming the suitability of ensemble learning methods for modeling nonlinear patterns in PV fault behavior. These results suggest that regression-based fault scoring can complement conventional fault classification approaches by providing a continuous decision-support indicator for condition monitoring and maintenance prioritization. Although the dataset is simulation-based, the selected variables correspond to measurable quantities commonly available in monitored PV plants, supporting the potential application of the proposed framework to real-world photovoltaic systems after experimental validation.

sciforum-183549: A descriptor-based machine learning framework for estimating pavement crack geometry from synthetic GPR hyperbolic responses

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Ground-penetrating radar has been used in pavement inspection for layer evaluation and anomaly detection. However, the inversion of radargram responses into quantitative crack geometry remains unresolved, particularly for narrow discontinuities expressed as localized hyperbolic signatures. This study presents a descriptor-based machine learning framework for estimating pavement crack width w and crack depth d from synthetic GPR data generated under controlled numerical conditions. A parametric dataset was generated in gprMax for top-down and bottom-up cracking configurations, varying crack width from 2 to 20 mm, crack depth from 2 to 10 cm, bituminous layer thickness from 5 to 20 cm, and the geometric parameter h_g from 10 to 50 cm. The simulated B-scans were processed in MATLAB to identify crack-related hyperbolic responses and to extract physically interpretable descriptors linked to temporal and amplitude behavior, including upper-event and lower-event two-way travel time, reflected amplitude, temporal separation, amplitude difference, and amplitude ratio. The resulting feature matrix was exported to Python, where Linear Regression, Support Vector Regression, and XGBoost were trained to estimate w and d. Model performance was evaluated using the coefficient of determination (R^2), root mean square error (RMSE), and mean absolute error (MAE). Descriptor availability analysis showed that 84.4% of the simulations yielded a complete upper–lower event pair, whereas 15.6% did not present a detectable lower event under the adopted tracking criteria, with a higher occurrence in bottom-up cases. The best width estimation was obtained with Linear Regression, with R^2 = 0.723, RMSE = 2.455 mm, and MAE = 1.410 mm. The best depth estimation was obtained with XGBoost, yielding R^2 = 0.535, RMSE = 1.339 cm, and MAE = 0.654 cm. Although developed on synthetic data, the proposed workflow provides a physically interpretable basis for future validation with laboratory and field GPR measurements.

sciforum-182004: Accelerating Analysis of Ultrasonic Test Data in Carbon Fibre Reinforced Polymers with Vision Foundation Models

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The aerospace industry is increasingly reliant on Carbon Fibre Reinforced Polymer (CFRP) components. The safety critical aspect of these components and complex manufacturing process entail a necessity for thorough non-destructive evaluation (NDT) inspection. Due to manipulator driven NDT delivery, the bottleneck of NDT has shifted to data interpretation. Despite the promise of artificial intelligence methods, widespread reliability concerns have stalled automation of inspection.

This work proposes vision foundation models for automated ultrasonic NDT data analysis. The approach leverages the generalisability of transformer architectures in absence of high volumes of data. Two vision foundation model encoders are fused with the weights kept frozen. To accommodate two ultrasonic data modes - B-scan and C-scan - the architecture employs a shared encoder and specialised decoder heads per domain. The model is fine-tuned through adapter blocks in a supervised manner on limited data, to perform pixel-wise segmentation of features such as sub-surface defects and structural echoes. This approach enables efficient detection, and characterisation of defects. An inherent advantage of this approach is cross-modal consistency; quantified via intersection between projected B-scan and C-scan predictions, providing an internal validation mechanism that improves confidence of detection.

Data in this work is acquired with a KUKA KR90 manipulator delivering phased array ultrasonic roller probe inspection of industrial grade CFRP components. Training dataset consists of inspection data from samples containing manufactured flat-bottom holes of varying sizes and a total of 2848 B-scans. Initial inference on a sample of 1348 B-scans with 25 defects shows all defects successfully detected and a mean dice score of 80% against 6dB threshold ground truth labels. These results imply excellent potential for detection and characterisation of defects. Further work will focus on comparative studies and generalisable defect segmentation on complex and challenging component geometries, more representative of industry settings.

sciforum-179831: Digital Structuring of Equine Upper Airway Endoscopic Findings for Machine Learning-Based Non-Destructive Diagnostics

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Endoscopy is a non-destructive diagnostic method widely used to evaluate equine upper airway disorders; however, interpretation remains subjective and depends on clinician experience. This study aimed to standardize endoscopic findings and establish a reproducible data pipeline for machine learning-based analysis within a non-destructive testing framework.

A total of 109 equine endoscopic examinations were retrospectively analyzed. The following pathological features were assessed using an expert-based scoring system: edema, hyperemia, upper tracheal mucus accumulation (0–3), lymphoid tissue hyperplasia (0–4), laryngeal paralysis (1–4), dorsal displacement of the soft palate, and dorsal pharyngeal collapse. Edema and hyperemia were the most frequent findings (75.2% and 69.7%, respectively). Tracheal mucus accumulation showed predominance of mild grades, while lymphoid tissue hyperplasia demonstrated a broad distribution across severity levels. Laryngeal paralysis (7.3%), dorsal displacement of the soft palate (9.2%), and dorsal pharyngeal collapse (5.5%) were less frequent.

The dataset is structured for supervised learning with clearly defined target variables. The primary task is the classification of tracheal mucus severity, implemented as both a binary (low [0–1] vs high [2–3]) and a multi-class (0–3) problem. Additional pathological features are included as auxiliary labels to enable multi-label analysis.

To ensure methodological rigor, data splitting is performed at the case level, and model evaluation is defined using cross-validation with accuracy, sensitivity, specificity, and F1-score. This study provides a justified and reproducible framework for transforming clinical endoscopic data into machine learning-ready inputs, supporting the development of objective diagnostic tools in equine respiratory medicine.

sciforum-181830: Liquid Flow Front Estimation From Ultrasonic Guided Wave Signals Using Machine Learning

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The reliable monitoring of liquid front progression during infusion processes remains a key challenge for the industrial deployment of out-of-autoclave lightweight composite manufacturing. This study investigates the use of ultrasonic guided waves for fluid front localisation in a bespoke liquid-only experimental setup, evaluating data-driven waveform modelling approaches and strategies for bridging the gap between simulated and experimental signals. A refined finite element simulation workflow is developed to reproduce the fundamental modal behaviour of experimental waveforms at substantially reduced computational cost when compared to other previously implemented models. A one-dimensional convolutional neural network trained directly on time-domain signals achieves a mean absolute error of 7.71 ± 2.11 mm across five independent infusion runs, outperforming the baseline energy-based functional approximation. To address the limited availability of experimental data, a conditional Generative Adversarial Network (GAN) is developed to bridge the gap between the simulated and experimental domains. When GAN-adapted synthetic data is combined with a single experimental dataset for training, the prediction error is reduced by 46% compared to training on experimental data alone, from 16.69 ± 0.86 mm to 9.07 ± 1.11 mm. These results demonstrate that waveform-based deep learning models, supported by GAN-adapted synthetic data, offer a promising and data-efficient route for accurate monitoring of resin flow in liquid composite moulding processes.

sciforum-181735: Multi-channel AE scalogram imaging with ML regression for non-invasive refrigerant flow characterization

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This study presents a novel non-invasive method for measuring the flow rate, phase composition, and density in two-phase CO_2 pipeline flows by combining multi-channel acoustic emission (AE) scalogram imaging with deep learning regression. The core innovation lies in the construction of multi-layered image tensors from continuous wavelet transform (CWT) scalograms from multiple acoustic emission sensor channels, which are stacked as image layers alongside pixel-uniform channels to encode the environmental parameters. With such an approach, the multi-sensor acoustic problem is converted into a multi-channel image regression task. This way, the direct application of state-of-the-art convolutional neural network (CNN) and support vector regression (SVR) architectures is enabled. The approach was validated on ultrasonic wave and residual AE data from a laboratory-designed CO_2 two-phase flow circuit that was operated under various frequencies and varying temperature, pressure, and flow conditions to induce different refrigerant phase states. An ensemble of multiple CNN and SVR architectures inferencing in parallel was evaluated, with the best-performing model achieving excellent overall metrics, such as R^2 and Pearson correlation coefficient. The proposed methodology is readily extensible to industrial applications that require non-invasive characterization of multiphase fluid properties, such as chemical processing, maritime fuel metering, and oil extraction pipelines.

sciforum-181996: Non-Destructive Detection of Plant Leaf Diseases Using Digital Image Analysis

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Early detection of plant diseases is essential for improving crop productivity and supporting global food security. Conventional diagnostic methods are often destructive, labor-intensive, and unsuitable for continuous monitoring. In this context, digital image-based approaches have emerged as a key component of non-destructive testing (NDT) in agriculture. This paper presents a comprehensive review of image processing and computer vision techniques for leaf disease detection, explicitly framed within NDT applications. The literature is systematically organized using a dual taxonomy based on feature representation (color, texture, morphological patterns) and learning paradigm (traditional machine learning versus deep learning), enabling a direct comparison of methodological capabilities and limitations. The analysis reveals that color-based methods are efficient but unreliable under variable illumination, while texture descriptors improve robustness in detecting structurally complex symptoms such as necrosis. Deep learning approaches, particularly convolutional neural networks, achieve high accuracy in controlled conditions (frequently above 90%) but exhibit performance degradation in field environments, with reported drops linked to background variability, occlusion, and inconsistent lighting. Across studies, a clear trade-off emerges between model accuracy and deployment feasibility, with high-performing models requiring large annotated datasets and significant computational resources. The review further identifies a lack of standardized evaluation protocols and limited cross-dataset validation as major barriers to practical NDT deployment. Although low-cost imaging platforms such as smartphone-based systems enable scalable data acquisition, their integration into reliable real-time diagnostic pipelines remains insufficiently addressed. In conclusion, this comprehensive review not only synthesizes existing methods but also highlights critical gaps that hinder the transition from controlled experiments to real-world NDT applications, particularly in terms of robustness, generalization, and system-level integration within precision agriculture.

sciforum-152449: Toward Real-Time FTIR Analysis: A Machine Learning Toolkit for Spectral Classification

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Accurate and efficient identification of chemical compounds is essential in various scientific and industrial applications. Vibrational spectroscopy techniques such as Fourier Transform Infrared Spectroscopy (FTIR) is a ubiquitous analytical technique that has been proven to be highly valuable method in chemical analysis as well as surface and materials characterization . In the context of high-throughput experiments, automatic data analysis methods are becoming essential, since manual data analysis is time -consuming process prone to human errors.

This study presents a machine learning approach that leverages FTIR data for the accurate identification of pure chemical compounds. We introduce a modular and interpretable ML framework that integrates classical chemometric preprocessing with robust supervised learning algorithms for FTIR spectral classification. Four classifiers—PLS-DA, XGBoost, Random Forest, and SVM—are evaluated on a chemically diverse set of pure compounds. Our tailored data extraction process effectively captures the major peaks characteristic of each compound, thereby enhancing the model's efficiency. Our results demonstrate that the used approach not only improves the identification accuracy but also reduces computational complexity, making it a robust tool for rapid and exact compound identification. Additionally, a researcher-friendly desktop application with an integrated GUI is presented to streamline the full pipeline.

This methodology holds significant potential for applications in pharmaceuticals, environmental monitoring, and chemical manufacturing, where swift and reliable compound analysis is paramount.

Session 3. Advanced Sensing Technologies

sciforum-180554: Non-Destructive Reflection-Mode Terahertz Characterization of Dye-Contaminated Aqueous Samples Using a Custom PTFE Liquid Cell

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Terahertz time-domain spectroscopy (THz-TDS) is a promising non-destructive technique for probing dielectric and interfacial properties of complex materials. However, aqueous samples remain challenging because water-rich media strongly attenuate THz radiation. This work proposes a reflection-mode THz-TDS strategy for assessing dye-contaminated aqueous samples using a custom polytetrafluoroethylene (PTFE) liquid cell compatible with the internal reflection configuration of the spectrometer. Measurements are performed with a TDS1008 spectrometer operating over 0.05–4.5 THz and using the SHR reflection mount, where the THz beam is redirected toward the sample plane at a fixed angle of 30°. The custom PTFE liquid cell is positioned directly on the SHR sample plane so that its lower planar base acts as the interrogated surface. Following the reflection protocol, a baseline is first recorded with the shutter closed, then a metallic mirror reference is acquired at the same sample plane, and finally measurements are taken for the PTFE cell filled with deionized water and aqueous dye solutions of different concentrations under unchanged acquisition parameters. The analysis focuses on robust observables from the reflected waveform, including temporal shift, peak-to-peak amplitude, RMS amplitude, and frequency-domain magnitude variations. Preliminary results indicated measurable differences in peak-to-peak amplitude, temporal shift, and spectral magnitude between the reference medium and dye-contaminated aqueous samples, supporting the feasibility of reflection-mode THz screening with the proposed PTFE cell. This study is designed to evaluate whether measurable differences in peak-to-peak amplitude, temporal shift, and spectral magnitude can be observed between the reference medium and dye-contaminated aqueous samples.

sciforum-175158: Generating Vegetation Health Index: A Composite Index for Monitoring Crop Health using Sentinel 2 Data and Google Earth Engine

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Advances in remote sensing have transformed real-time crop health monitoring and precision agriculture by enabling large-scale, non-invasive, and multi-temporal assessment of crop conditions. In this study, we developed a composite Vegetation Health Index (VHI) that integrates three key biophysical parameters—Leaf Area Index (LAI), Canopy Chlorophyll Content (CCC), and Canopy Water Content (CWC)—to provide a robust and holistic evaluation of crop health. Sentinel-2 surface reflectance imagery was processed using the Biophysical Processor in ESA's Sentinel Application Platform (SNAP) to extract these parameters, with LAI validated against field measurements from a Li-COR LAI 2200c plant canopy analyzer, yielding an R^2 value of 0.65. This indicates that the model shows a moderate to strong agreement between satellite-derived and field-measured LAI, demonstrating the model's suitability for large-scale crop health monitoring despite inherent uncertainties in remote sensing-based estimations. The study was conducted at the Indian Agricultural Research Institute (IARI), covering an area of over 250 hectares, with satellite data acquired on 9th March 2025—a cloud-free day during the Rabi season. To enable rapid, scalable, and repeatable monitoring, the workflow was integrated with Google Earth Engine (GEE), allowing efficient analysis of multi-spatial and multi-temporal datasets without the need for complex local preprocessing. CCC and CWC were directly obtained from SNAP outputs, while all parameters were normalized using min–max scaling and combined through equal-weighted linear aggregation to produce the VHI, ranging from 0 (poor health) to 1 (good health). This integrated approach harnesses the computational power of GEE and the strengths of multiple biophysical indicators, providing a valuable tool for timely crop health assessment, early stress detection, and informed decision-making in precision agriculture.

sciforum-181759: Non-destructive testing of nanorough substrates for biomedicine and optoelectronics applications

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Modern methods for measuring the heterogeneities of nanosurfaces are divided into contact and non-contact approaches. Among contact measurement methods, optical methods are distinguished, which are characterized by high measurement accuracy in the nanometer/subnanometer range. It is possible to select stylus profilometers or AFM, but the mechanical damage of the sample imposes restrictions on these methods. Non-contact (optical) methods, like confocal microscopes or correlation-optical (interferometric) methods, are non-destructive. They enable us to achieve a sub-nanometer resolution for measuring height surface roughness parameters, with a limit in the transverse direction by the Abbe diffraction criterion. Regarding testing nanostructured surfaces, such as substrates for touch displays, bioimplants, or membranes of biological cells, sensitive and non-destructive full 3D nanotopography becomes possible. We propose a novel non-destructive method based on the principle of super-resolution STED microscopy, overcoming the diffraction limit to measure both height and spatial roughness parameters and 3D surface reconstruction with nanometer accuracy. As surface probes, luminescent carbon nanoparticles with a size of about 30 nm and a significant dipole moment, distributed over the surface area in an external electric field, are used. The specially designed optical setup using structured optical beams provides a pathway to overcome the diffraction limits imposed by the Abbe resolution criterion, enabling a spatial resolution corresponding to the nanoparticle size. The particle's luminescence intensity linearly depends on the local surface height in a range of inhomogeneities up to 100 nm, which enables the effective testing of nanoroughness with an RMS of about 5-15 nm. The use of AI/ML for surface reconstruction based on irregular coordinate values of luminescence intensity is expected. The proposed approach can be applied for non-destructive surface parameter testing and 3D nanotopography of nanostructured surfaces like cell membranes, titanium substrates for bioimplants, or glass substrates for optoelectronic devices.

sciforum-183370: Three techniques for characterizing materials using microwaves

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We present an MTM microwave sensor that, by using three different techniques, can characterize solid, liquid or gaseous samples regardless of whether the permittivities of the samples are high or very low. Materials exhibit a wide range of dielectric responses depending on their composition and structure, with some having a high permittivity, while others exhibit low permittivity associated with weak polarization effects. Similarly, dielectric losses can vary significantly, with certain materials showing high loss tangents and others behaving as low-loss media. Furthermore, the dielectric properties of many materials are strongly influenced by external factors such as temperature, humidity, pressure, and aging, leading to significant temporal and environmental variability. Other materials maintain relatively stable dielectric behavior under similar conditions. Microwave characterization techniques provide a non-invasive and reliable approach for extracting dielectric parameters. In resonant-based methods, the interaction between the electromagnetic field and the material under test produces measurable changes in the system response, such as shifts in resonant frequency, variations in insertion and return losses, and changes in resonance bandwidth or quality factor. These variations can be exploited to infer material properties, including permittivity, loss characteristics, and frequency-dependent behavior, enabling accurate and repeatable measurements. This work presents measurements of: 1) humidity variations in sliced potatoes, inferred from shifts in a single resonant frequency of a resonant structure; 2) salt and chlorine in water, evaluated using insertion loss from a frequency-comb response; and 3) sulfur hexafluoride concentration within a cell, determined from the quality factor of a single resonance. In the first case, potatoes exhibit moderate permittivity values that vary significantly with humidity. In the second case, water presents a high permittivity, and small contaminant concentrations do not significantly affect this parameter. Finally, SF_6 exhibits very low permittivity, resulting in imperceptible variations in the real part of the effective permittivity of the samples.

sciforum-176732: AI Wearable Biosensing Device Equipped with Inertial Measurement Sensors and Electromyography Sensors for Early Detection of Parkinson's Disease

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Parkinson's disease is a progressive neurodegenerative disease resulting in motor symptoms including muscle rigidity, resting tremor, bradykinesia, and postural instability. Given that the diagnosis is primarily clinical, early symptoms can be overlooked, underscoring the need for improved methods of early detection. Wearable biosensor devices that use highly sensitive motion sensors can detect slight motor fluctuations including subtle tremors and gait irregularities. Data collected from these devices can be analyzed by machine learning algorithms to identify motor abnormalities associated with Parkinson's disease, enabling early diagnosis and improved management. The aim of this study is to develop a wearable biosensor device integrated with machine learning to detect subtle early motor changes that may be linked to Parkinson's disease. The wearable device is designed to integrate inertial measurement unit sensors (IMU) including accelerometers, which detect tremor amplitude; gyroscopes, which measure angular velocity to determine tremor frequency; and magnetometers, which track posture and rotation. The device also incorporates electromyography (EMG) sensors to monitor rigidity, arm swing, and muscle contraction patterns, in addition to physiological sensors to track autonomic function. Machine learning training will be conducted to allow pattern identification of motor changes consistent with Parkinsonian motor dysfunction. Validity will be assessed by comparing sensor-derived measurements with clinical evaluations to determine its detection reliability. We expect that wearing these devices will enable accurate detection of early Parkinson's disease symptoms allowing for early treatment intervention and potentially slowing disease progression. Early detection of Parkinson's disease identifies pre-motor and non-motor signs, occurring before the loss of over 50% of dopaminergic neurons, facilitating timely neuroprotective treatment that may slow symptom progression.

sciforum-183357: Defect Evaluation in Ferromagnetic Materials Using a Custom-Designed Instrument for Magnetic Barkhausen Noise and Hysteresis Loop Measurements

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Defect detection is critical for ensuring the safety and reliability of ferromagnetic components, while accurate defect-depth evaluation is required to assess damage severity and support maintenance decisions. This study investigates the use of magnetic Barkhausen noise (MBN) signals and hysteresis loop, or BH curve measurements for evaluating defect depth in ferromagnetic materials. The theoretical framework is based on the magnetisation process and magnetic domain-wall motion. Under identical testing conditions, the presence of defects is expected to disturb the local magnetic response and reduce the effective magnetic domain activity, resulting in a weaker MBN signal. Simulations are first conducted to analyse BH curve variations caused by defects with different depths, providing guidance for subsequent experimental verification. Two types of defects are considered in the experiments: crack defects and welding defects. Different sensor probes are designed and applied according to the defect type and measurement requirements. The results show that variations in defect depth produce consistent trends in the simulated BH curves and experimentally measured MBN signals. These findings confirm that MBN measurements are sensitive to defect-depth variations and are consistent with the theoretical analysis. Furthermore, defect mapping based on MBN signal features provides an effective indication of defect distribution and depth, demonstrating the potential of the proposed magnetic method for non-destructive defect evaluation in ferromagnetic components.

sciforum-181796: Examination of filled polymers by AFM phase imaging

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Atomic force microscopy (AFM) is not only suitable for imaging surfaces with nanometer-scale resolution, but also for investigating various mechanical and other physical properties of the sample surface. This is enabled by the AFM measurement principle, in which a cantilever with a fine tip at its end mechanically scans the surface. Scanning can be performed in contact mode or, when the cantilever oscillates, in tapping mode.

In most AFM modes, the distance between the tip and the surface ranges from 0.1 nm to 10 nm. In tapping mode, the cantilever is subject to both long-range attractive forces and short-range repulsive forces, which is why the oscillation amplitude must be optimized to prevent these effects from compromising contrast and resolution.

In addition to simple topography measurement, various other modes can be unambiguously measured, including phase and amplitude. While both of these modes highlight edges, the phase also depends on the sample hardness, the surface elasticity, and the adhesion between the sample surface and the tip, thereby enabling a qualitative distinction between different materials on a surface.

Here, we report on investigations of various polyamide (PA 12) blends with glass fibers, which were examined by AFM phase imaging, and compare the results with those obtained from Raman microscopy. The AFM measurements were performed by a FlexAFM Axiom (Nanosurf) in tapping mode with Tap190Al-G cantilevers; Raman microscopy was performed using a WITec alpha300 apyron microscope.

The results underscore that AFM phase imaging is a versatile tool for distinguishing between different materials on a surface and suggest that further investigations of polymer blends are warranted to gain a better understanding of the quantitative phase differences measured by AFM.

sciforum-181012: Non-destructive estimation of crop nitrogen using Proximal Hyperspectral Remote Sensing

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Hyperspectral remote sensing made a significant breakthrough in precision agriculture by providing accurate estimates of important crop health indicators. Canopy nitrogen content (CNC) is one of the major crop traits that need to be monitored in a timely and accurate manner for making timely decisions regarding input applications. In the present study, a hybrid retrieval model was developed by combining the physically based PROSAIL-PRO radiative transfer model (RTM) and Gaussian process regression (GPR) for the non-destructive estimation of CNC in wheat crops in the experimental fields of ICAR—Indian Agricultural Research Institute, New Delhi, India. The proximal non-imaging hyperspectral data in the wavelength region of 400-2500nm and spectral resolution of 1nm were collected in situ using an ASD FieldSpec Spectroradiometer. Principal component analysis (PCA) and active learning (AL) techniques were employed to reduce the dimensionality in the spectral and sampling domains, respectively. The validation results showed that this hybrid approach successfully retrieved CNC with an R^2 of 0.71 and NRMSE of 14.36%. Moreover, a low relative uncertainty below 35% supports the broad applicability and portability of the retrieval model. Upscaling this hybrid retrieval workflow to farmers' fields can facilitate operational delivery of important crop traits, enabling effective monitoring of crop growth and production.

sciforum-181766: Non-interferometric visualization of 3D speckle field singularity structure

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Characterization of the speckle field structure is an actual task in non-destructive diagnostics of distant phase-inhomogeneous objects, like rough surfaces. In 2D, the speckle field singularities (optical vortices) are zero-intensity points, while in 3D space they can form complex structures, like closed links and knots. Traditionally, for visualization of such structures, interferometric techniques are used. In the case of diagnostics of speckle patterns on distant objects, the reference wave cannot be used, so non-interferometric methods become important. We propose the visualization of 3D speckle field zero lines using fluorescent nanoparticles, optically trapped at intensity minima regions. For such purposes, the refractive index of the particle should be less than that of the surrounding medium. The action of gradient optical force will move particles to the intensity minimum (or absolute zero in 3D), where the action of longitudinal scattering force is absent. The additional light source is used for particles' fluorescence excitation. The speckle field is formed due to the free space propagation at the Fresnel or Fraunhofer diffraction zone or in a focal region of the lens by focusing the object field. Visualization of 3D speckle field singularities can be produced in a high-volume region of nanoparticle solute, or reconstructed from the 2D planes, due to the axial scanning along the z-axis.

sciforum-181809: Optimization of Bloch-like surface wave sensors via multi-nanostrips on side-polished photonic crystal fibers

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Electromagnetic surface waves have revolutionized label-free optical sensing due to their extreme sensitivity to refractive index (RI) variations at propagation interfaces. Among these, Bloch-like surface waves (BLSWs) excited in side-polished photonic crystal fibers offer a superior alternative to traditional surface plasmon resonance by providing higher figures of merit (FOM) and narrower resonance peaks.

This work proposes a novel multi-nanostrip configuration on a D-shaped PCF to optimize sensor sensitivity by analyzing the interactions of multiple TiO2 nanostrips as a function of the spatial gap between them. The spatial gap between multiple TiO2 nanostrips can act as a high-intensity focal point for the electric field. By confining the BLSW mode within these narrow regions, where the external medium is located, a stronger light-matter interaction is achieved compared to single-strip designs. This field confinement enables the detection of refractive index (RI) variations within extremely small analyte volumes, enhancing diagnostic precision in confined or complex environments.

This study employs the finite element method and eigenmode expansion to analyze how sensitivity and the figure of merit (FOM) vary as functions of the number of strips and the spacing between them (GAP). This computational analysis identifies the optimal geometry that balances sensitivity and FOM, ensuring a robust sensing configuration for real-world applications such as industrial monitoring and biological or chemical diagnostics. This advancement in nanosensor design represents a key step toward high-precision sensing technologies for non-destructive diagnostics.

The computational analysis reveals that a configuration of three 10 μm nanostrips with a 0.1 μm GAP enhances sensitivity by 17% compared to single-strip benchmarks, achieving a peak FOM of 2400 RIU^{-1}. These results demonstrate the sensor's capacity to detect minute RI shifts in industrial lubricants. This provides a robust NDT tool for monitoring metallic wear particles, water contamination, or thermal degradation in high-precision machinery.

sciforum-181817: Taper-Like Longitudinal Variations in Etched SMS Fibers: Modal Evolution and Spectral Response for Optical Sensing

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Since their early development, fiber optic sensors have established themselves as functional tools in industrial and scientific applications. Among them, interferometric configurations based on singlemode–multimode–singlemode (SMS) fibers have become attractive due to their ease of fabrication, low cost, and high sensitivity. Their spectral response is governed by multimode interference (MMI) within the multimode fiber (MMF) section.

In etched SMS (E-SMS) configurations, the reduced MMF diameter increases the overlap between the guided optical field and the surrounding medium, which is directly related to refractometric response and is relevant for non-destructive optical sensing schemes. However, most analyses assume longitudinally uniform geometries, where the modal power distribution P_m (z) remains approximately invariant along the propagation coordinate z. This limits the understanding of how longitudinal variations, such as taper-like longitudinal diameter variations, influence modal evolution and external-field interaction, and the resulting transmission spectrum.

In this work, a computational framework is developed to compare a uniformly E-SMS structure with configurations exhibiting taper-like longitudinal diameter variations in the MMF section. The analysis focuses on how these axial geometry changes affect the evolution of the modal amplitudes along the propagation coordinate z and, consequently, the redistribution of optical power within the device. A power-normalized modal decomposition is used to obtain the longitudinal modal amplitudes $a_m(z)$ and corresponding modal power distributions $P_m(z) = |a_m(z)|^2$, allowing the excited modes in both configurations to be identified and their contribution to MMI to be examined. In addition, a mode-resolved external interaction factor is introduced from the electric-field energy in the surrounding region, linking modal evolution with field exposure to the external medium. In this way, the framework is intended to assess how taper-like longitudinal variations may promote clearer transmission features and provide a physically grounded basis for comparing the sensitivity potential of both configurations in non-destructive optical sensing applications.

Session 4. Robotics and Automation in NDT

sciforum-182070: Cooperative Mobile Robot Swarm for Non-Destructive Structural Inspection Using Backstepping–SMC Control

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Non-Destructive Testing (NDT) necessitates thorough and dependable evaluations of structures within intricate and cluttered settings. Utilizing robotic swarms presents a feasible method to automate such processes, offering synchronized, efficient, and scalable inspection features. This document introduces a simulation-based system tailored for autonomous NDT inspections, employing a collective of differential-drive mobile robots developed in MATLAB/Simulink. Each individual robot is managed through a hybrid Backstepping–Sliding Mode Control (SMC) approach, which guarantees accurate trajectory adherence and resilience against disruptions. A leader–follower arrangement orchestrates the swarm, enabling follower robots to sustain ideal relative placements for effective coverage. To facilitate safe movement near inspected areas without jeopardizing the formation's stability or trajectory precision, obstacle avoidance is incorporated using an artificial potential field technique. The simulation outcomes depict the paths of both leader and follower robots, the preservation of the formation, and the successful navigation around obstacles in a cluttered environment that mirrors typical industrial or structural conditions. Metrics assessing performance, including root-mean-square tracking error, deviation in formation, and inspection coverage, validate the effectiveness of the introduced method. A comparison between configurations using a single robot and those using a swarm reveals considerable advancements in both inspection efficiency and durability. The outlined framework offers a thorough simulation exploration that demonstrates how cooperative mobile robot swarms, directed by Backstepping–SMC control and formation tactics, can notably improve autonomous NDT operations. This research establishes a basis for the forthcoming development of multi-robot NDT systems applicable in industrial contexts.

sciforum-171959: Drone-Supported Multi-Risk Inspection Model for OCCUPATOONAL Health and Safety in Confined Areas

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Confined and high-risk working environments pose significant challenges in terms of occupational health and safety (OHS) due to limited accessibility, restricted visibility, and exposure to multiple hazards. This study proposes a drone-assisted inspection model for the assessment of multi-risk conditions in such environments. Recent advancements in unmanned aerial vehicle (UAV) technologies have created new opportunities for remote inspection, particularly in areas where human access is difficult or hazardous. Drone-supported inspection systems have emerged as an innovative solution for non-destructive testing (NDT) and risk monitoring applications.Indoor drones equipped with protective cage structures, collision-resistant frames, high-lumen lighting systems, thermal cameras, LiDAR-based positioning, and real-time image transmission capabilities demonstrate considerable potential for confined space inspections. However, a review of the existing literature reveals that most studies focus either on confined space safety procedures or on technical UAV applications. Comprehensive models integrating drone-assisted inspection into a structured OHS management system from a multi-risk perspective remain limited.

The proposed model consists of four main stages: preparation, UAV-assisted risk detection, hazard classification, and reporting. To demonstrate its applicability, a scenario-based case example was developed, comparing traditional inspection methods with the proposed drone-assisted approach. The findings indicate that the drone-supported method increases the scope of risk detection, reduces inspection time, and significantly decreases inspector exposure, particularly in inaccessible and high-risk areas.

This approach provides an innovative contribution by integrating UAV technology into OHS inspections through a multi-risk management perspective and offers a practical roadmap for safer and more effective occupational inspections in confined environments.

sciforum-174450: High-Precision Piezoelectric Sensor Positioning with SMC Control for Robotic NDT in Pipelines

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Non-destructive testing of confined pipelines requires high-precision sensor positioning under nonlinear and dynamically constrained operating conditions. This work presents the design, modeling, and closed-loop control of a compact piezoelectric-driven positioning mechanism for ultrasonic pipeline inspection in internal diameters of 50–100 mm. The system employs a multilayer PZT-5H stack actuator integrated with a rack-and-pinion transmission and radial flexure guidance to convert micrometer-scale axial displacement into precise radial deployment. A corrected displacement-source actuator model based on the Generalized Bouc–Wen formulation is developed to capture electromechanical coupling, preload interaction, and rate-dependent hysteresis dynamics. To compensate for hysteresis nonlinearities and parameter uncertainty, an improved Sliding Mode Controller incorporating derivative damping, integral action, feedforward compensation, filtered switching dynamics, actuator saturation, and anti-windup compensation is developed and validated through high-fidelity Simulink simulations. The filtered unsaturated controller achieved a rise time of 23.20 ms, settling time of 153.00 ms, overshoot of 0.14%, and near-perfect steady-state tracking accuracy. Under practical actuator voltage constraints (0–100 V), the final filtered saturated controller maintained stable near-aperiodic operation with bounded control effort, achieving a rise time of 86.58 ms, settling time of 236.35 ms, and overshoot of only 0.23%. Hysteresis suppression analysis demonstrated substantial reduction in loop distortion and improved tracking consistency across multiple excitation frequencies. The results establish a physically realizable nonlinear control framework for robust high-precision piezoelectric positioning in autonomous pipeline inspection systems.

Session 5. NDT for Structural Health Monitoring

sciforum-182163: Ground- and Space-Borne Interferometric Radars for Monitoring Cable-Stayed Bridges: A Multi-Scale Monitoring Framework

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Maintaining large-scale transport infrastructure is a significant challenge because transport networks consist of many interconnected assets where a localised failure can cause widespread disruption. This study proposes a monitoring framework that connects the wide-area screening capabilities of Interferometric synthetic Aperture Radar (InSAR) with the high-precision diagnostic power of Ground-Based Interferometric Radar (GBIR). Within this architecture, satellite remote sensing is positioned as a continuous observation layer. By taking advantage of frequent revisit times and millimetre-scale sensitivity to movement, the framework uses optimised satellite data acquisition to ensure observations are conducted at scales suitable for bridge monitoring. This offers a practical solution for asset owners to assess infrastructure conditions and plan preventive maintenance across vast networks without the need for frequent expert visitation.

In this integrated framework, GBIR is used to establish a high-fidelity "structural footprint" of the bridge's health status. While the satellite-based observation is intended to provide long-term tracking and identify general changes [1], the ground-based system captures the rapid structural vibrations required for detailed health characterisation through Operational Modal Analysis (OMA) [2]. This approach is discussed through the case study of the Dong-Yi Bridge, a cable-stayed bridge in South Korea, where GBIR was deployed to record the baseline structural response as a definitive benchmark of the healthy state. The study highlights the potential for a cohesive monitoring pipeline where a radar satellite monitors for anomalous trends, which in turn justifies the targeted deployment of GBIR for in-depth structural inspections. The synergy between these technologies provides a robust and reliable basis for transitioning from schedule-based to trigger-based infrastructure management and informed decision-making.

sciforum-181937: Laser Profiling as a Screening NDT Tool for the Evaluation of Ride Quality Anomalies at Road–Bridge Transition Areas

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Bridge inspection and maintenance planning at heavy-duty motorways constitute a significant cost concern for roadway operators. Bridge approach areas and expansion joint restoration may require substantial budgets and, most importantly, traffic management measures like lane closures. This creates a need for targeted and evidence-based actions supported by reliable non-destructive testing (NDT). In this context, this study explores the use of laser profilers, already widely applied in pavement condition assessment procedures, as a rapid screening tool for identifying anomalies in ride quality near bridge–pavement transitions. From this sense, an additional value of an already well-established NDT tool can be revealed.

The methodological approach is based on the analysis of longitudinal profile data collected along selected heavy-duty motorway segments, including representative technical structures, and in particular, bridges and jointed transitions. Periodical measures and evolution of ride quality indicators, including the International Roughness Index (IRI), are examined to detect localized increases in roughness and change patterns or IRI growth rates over time. Year to year variations can pinpoint critical issues, including differential settlement, joint deterioration, or stiffness discontinuities.

The proposed framework can help toward an informative and justified decision-making through highlighting locations after laser screening instead of investing on detailed and time-consuming structural diagnostics. Minor maintenance actions, like localized asphalt treatments to restore surface regularity, or needs for additional and targeted investigation can follow the laser profiling data analysis. Within this framework, IRI is evaluated not only as a standard indicator of pavement ride quality, but also as a proxy measure reflecting the condition of road–bridge transition zones.

sciforum-181275: Non-Destructive Multi-Sensor UAV Surveying for Monitoring Rockfall-Prone Road Sections

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Rockfall events can pose a direct and significant threat to road safety, particularly in mountainous and coastal regions where slope instability can cause sudden and hazardous disruptions. Conventional inspection methods are nowadays less popular because of accessibility constraints, safety risks for human personnel, and insufficient monitoring frequency. Besides, rockfall events can significantly impact pavement performance by accelerating surface deterioration and structural damage. Thus, early identification of high-risk zones enables timely interventions, helping to preserve pavement integrity and prevent the development of extensive failures that threaten human life, disrupt mobility and require costly rehabilitation.

This study explores the use of Unmanned Aerial Vehicle (UAV) sensing as a Non-Destructive Testing (NDT) approach for early detection and assessment of rockfall-prone areas near roadways, aiming to enhance safety and ensure uninterrupted road traffic. In particular, an UAV is employed to acquire high-resolution multimodal data, including optical imagery for Structure-from-Motion (SfM), LiDAR, and thermal data, over a vulnerable road section in North Greece. The proposed framework focuses on qualitative and semi-quantitative interpretation of aerial data to identify indicators of instability, such as fractured rock masses, debris accumulation, and evolving slope conditions.

In terms of its contribution, the presented approach supports rapid deployment and repeatable inspections, consistent with non-invasive monitoring principles. UAV-assisted inspections provide a flexible and scalable solution that contributes to life safety, and road infrastructure resilience, by enabling timely interventions and supporting the targeted placement of protective measures, such as rockfall barriers and wire meshes, along high-risk sections.

sciforum-183322: Real-Time Monitoring and Visualization for Intelligent Compaction of Asphalt Pavements Based on Ground-Penetrating Radar

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Ground-penetrating radar (GPR) has been implemented as a promising sensing technique for intelligent compaction for rapid, non-contact, and continuous estimation of asphalt pavement dielectric properties during construction. Since dielectric constant is strongly correlated with asphalt mixture density, GPR measurements can be used to infer the spatial distribution of compaction quality. However, field implementation remains challenging because signal stability is easily degraded by water films on the pavement surface and by antenna vibration under roller operating conditions. Existing studies have also focused primarily on laboratory-scale dielectric–density relationships and density prediction, with limited attention to an integrated field-oriented framework for real-time processing and visualization.

This study presents an automated GPR-based system for real-time compaction quality evaluation and visualization in asphalt pavement construction. The system includes hardware selection based on field requirements for data quality, spatial resolution, and real-time response; a modified mounting structure that improves signal stability under strong vibration; and a synchronization strategy that combines timestamps with path interpolation to align GPR and GPS-RTK data. A standardized processing workflow based on the surface reflection method was established to calibrate, detect, and correct dielectric constant measurements under the coupled effects of surface water and mechanical vibration. An automated software platform was developed to realize real-time denoising, spatial mapping of the construction area using an Alpha-Shape-constrained method, repeated compaction identification with temporal updating, and dynamic generation of compaction and temperature heatmaps.

Field experiments conducted on a highway project in China demonstrated the stability, timeliness, and engineering applicability of the proposed system. The measured average PWL ranged from 96.4 to 97.4, and the generated heatmaps effectively captured the spatial distribution characteristics of compaction quality and temperature. The proposed method provides a practical framework for real-time field compaction quality control.

sciforum-181977: A simplest Approach for Plotting the Disperison Curves in a Layered Composite Material Using the Floquet-Bloch Boundary Condition

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Structural health monitoring via guided waves has been a major player in material inspection and damage identification, as they travel long distances with relatively low attenuation, holding valuable insight about the structural integrity of the material. Nevertheless, this method needs a pre-understanding of the dispersive nature of the waves in order for a prompt identification of any eventual damage in the structure, thus, the importance of solving the dispersion relation.

In the case of anisotropic materials, for example composites, many methods have been implemented for solving the dispersion curves and which are robust and require expertise and mathematical background to solve analytically, such as Transfer Matrix Method (TMM), Global Matrix Method (GMM), Stifness Matrix Method (SMM), and Semi-Analytical Finite Element method (SAFE).

In this regard, this study proposes a simplest approach using the Floquet-Bloch periodic condition, which reduces the propagation problem to a unit cell, that is the smallest repeated cell possible in the structure. In other words, it considers the propagation in the first Brillouin zone only as it captures the eigenfrequencies that correspond to specific wave number values and which represent the modes propagating in the structure. As a result, Lamb waves dispersion curves in a layered CFRP composite laminate will be plotted using the Floquet-Bloch periodicity, as well as an analysis of the displacement in each layer of the CFRP.

sciforum-182128: Advanced Diagnostic of Subsurface Decay in Rigid Airfield Pavements: A Signal-Processing-Enhanced GPR Approach

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The condition of airfield pavements is critical for ensuring the safety and efficiency of airport operations. Compared with highway pavements, runways and taxiways are subjected to heavier and more repetitive dynamic loading, which can lead to complex subsurface decay mechanisms that are not easily detected through surface inspection. Among these, mud pumping is particularly damaging, as it accelerates the deterioration of rigid concrete slabs.

Mud pumping occurs when water accumulates at the interface between a concrete slab and its supporting layers. Under repeated loading, a slurry of water and fine particles is expelled through joints and cracks, leading to subsurface voids, loss of support, and eventual structural failure. Performing an advanced diagnostic of these features at an early stage is essential for effective maintenance [1].

This study presents a collaborative investigation between academia and Heathrow Airport to assess the capability of Ground Penetrating Radar (GPR) as a primary non-destructive tool for diagnosing early-stage pavement decay. While GPR provides high-resolution subsurface data, the interpretation of these data remains a key challenge, particularly in complex pavement environments.

To address this, the study emphasises signal-processing-enhanced approach to improve data interpretability [2]. By enhancing the visibility and contrast of subsurface responses and analysing signal behaviour beyond conventional time-domain representations, the approach aims to extract more reliable diagnostic indicators of moisture accumulation, void development, and layer interfaces' misalignment.

The results demonstrate that improving data interpretation is essential for the accurate diagnosis of decayed pavement states. This supports a shift toward more proactive, data-driven maintenance strategies for airfield infrastructure.

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sciforum-181976: An Autonomous GPR-Based Scanning Frame for Reinforced Concrete Structures

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Ageing reinforced concrete infrastructure demands reliable, cost-effective condition assessment to support timely interventions and extend asset service life, directly contributing to SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities). Ground Penetrating Radar (GPR) is a key non-destructive testing (NDT) method for this purpose, yet surveys are often executed manually, leading to inconsistencies in coverage, positioning and scan repeatability that limit robust, data-driven evaluation.

This work presents an autonomous robot-mounted GPR system capable of conducting controlled, repeatable surveys of reinforced concrete elements with minimal human intervention. The autonomous robotic platform follows prescribed trajectories, regulates scanning speed and stand-off, and records positional information to generate spatially consistent radargrams that can be directly linked to experimental layouts. It is conceived as an experimental and methodological backbone for corrosion and degradation studies, and as a stepping stone towards more advanced robotic inspection solutions in real structures.

Tests were performed on reinforced concrete specimens to demonstrate that the system reduces operator-dependent variability and produces structured GPR datasets suitable for repeated measurements over time on the same elements, as well as for integration with complementary techniques and machine learning-based analysis. The proposed framework standardises acquisition conditions and embeds automation at the data collection stage, advancing digitalised NDT workflows and supporting more reliable, evidence-based decision-making for the maintenance and life-cycle management of concrete infrastructure.

sciforum-180689: Automated Electrical Resistance Data Acquisition for Fatigue Deformation Detection Using a Keithley 6221 and LabVIEW

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Metals are widely used in various types of structural applications, such as in the automotive, aerospace and construction industries. However, their service life is limited due to the various loads they experience during operation. Specifically, cyclic loading can lead to early fatigue failure of these structures. Therefore, early detection of fatigue deformation is essential to prevent catastrophic failures. In this study, an automated electrical resistance data acquisition system was developed using LabVIEW to obtain measurements from a Keithley 6221 current source for fatigue damage detection. The results showed an increase in electrical resistivity after the application of cyclic loading. It was observed that electrical resistivity increased after each set of loading cycles, with an average increase of 7.38% a stress level of 260 MPa (high cycle fatigue), and a 6.5% increase after the application of 25,000 cycles at 165 MPa (low cycle fatigue). Scanning Transmission Electron Microscopy (S/TEM) was used for microstuctural investigation as a proof of concept for the high-cycle-fatigue sample interrupted after 25,000 cycles to analyse the modification in dislocation structures, as well as the qualitative increment in the dislocation density with respect to the initial microstructural state of the as-machined sample. Such a modification in dislocation structures as well as increment in dislocation density corroborates the findings proposed by electrical resistivity measurement. The results demonstrated that electrical resistivity measurement provides a promising non-destructive approach for the early detection of fatigue damage in metallic materials.

sciforum-183518: Bridging the gap: Enhancing structural damage localization accuracy using multi-modal sensor fusion

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Electromagnetic interference and signal attenuation make traditional piezoelectric sensors (PZT) more susceptible to unreliable structural health monitoring outcomes. This study proposes a novel, multi-modal sensing framework that fuses electrical PZT actuation with optical fiber Bragg grating sensing to achieve robust damage localization. An end-to-end 1D-convolutional neural network is designed to process raw temporal wave signals across a broadband frequency range of 50–250 kHz. Unlike conventional methods that rely on manual, physics-heavy feature extraction, the proposed convolutional neural network architecture learns temporal and spatial wave–damage interactions directly from standardized 1D signals. The model is validated using a five-fold cross-validation scheme and an extensive ablation study to facilitate scientific rigor. The results demonstrate a significant improvement in performance. While a PZT-only configuration achieved an accuracy of only 27% (near-random), the hybrid fusion model achieved an aggregated accuracy of 66% and a Macro-F1 score of 0.66. The model shows good sensitivity in distinguishing symmetric damage locations and identifying remote damage sites. This research provides a data-driven justification for hybrid sensing architectures, proving that the integration of optical strain data with electrical excitation is essential for overcoming the signal-to-noise limitations of monomodal structural health monitoring systems. This framework offers a good scalable, interference-immune solution for real-time aerospace and civil infrastructure monitoring.

sciforum-181384: Degradation Monitoring of Reinforced Concrete Structures by NDT: laboratory and field applications

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Reinforced concrete (RC) structures are fundamental to infrastructure and form the backbone of modern construction. However, these structures progressively degrade over time due to factors such as mechanical loading, material aging, environmental exposure, and steel reinforcement corrosion. Their assessment is therefore essential for ensuring structural safety, optimizing maintenance costs, and extending service life. Traditional inspection methods for RC structures are often destructive, time-consuming, subjective, and limited to localized areas. In contrast, Non-Destructive Testing (NDT) techniques can evaluate a wide range of structures quickly, at low cost, and with high resolution, without causing damage. Nevertheless, each NDT method has specific strengths and limitations, making integrated approaches particularly valuable. Recent studies demonstrate that combining NDT techniques can improve diagnostic accuracy, reduce uncertainties, and provide a more comprehensive and quantitative understanding of structural conditions. At this stage, the research proposes the integration of NDT approaches (GPR, ERT, SP, and UPV) to monitor damage, material properties, steel reinforcement type, and the overall condition of RC structures. For this purpose, laboratory experiments and field investigations on real structures have been conducted. In the laboratory, RC specimens have been evaluated using both direct and indirect testing methods. In the field, structural elements from a previously demolished bridge, including beams and columns recovered and transported to the laboratory, have been analyzed to enable comparison between newly prepared specimens and real components that were previously in service. However, multisensor geophysical methods generate large and complex datasets that require advanced processing and interpretation. In this context, Artificial Intelligence (AI), particularly machine learning and deep learning models, offers powerful tools to automatically detect, classify, and quantify structural damage, as well as to facilitate efficient data interpretation.

sciforum-183556: Development of a UAV-Mountable Multimodal Radar System with Deep Learning for Structural Health Monitoring

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Aging bridge infrastructure in the United States presents critical safety risks and economic burdens. Early detection of structural deterioration can significantly reduce maintenance costs and prevent catastrophic failures. Post-earthquake safety evaluation of buildings also requires rapid assessments in the affected area. However, current structural health monitoring practices rely primarily on visual inspections and localized testing and are slow, labor-intensive, and insufficient. Ground Penetrating Radar (GPR) provides a promising alternative or complementary approach, enabling fast, non-destructive evaluation of large structures by revealing internal features such as reinforcing bars, voids, and delamination. This study aims to develop a lightweight, compact GPR system mountable on an unmanned aerial vehicle (UAV) enabling rapid scanning of hard-to-access or hazardous locations and potentially detecting issues in stability, stiffness, and internal cracks, while ensuring operator safety. What differentiates this work from others is the use of software-defined radio (SDR), enabling the operation of multiple GPR methods without hardware alterations, unlike conventional radar systems. Software implementation allows flexible switching between GPR modes (impulse, SFCW, and custom methods) with power and frequencies selected for a specific target.

Moreover, our laboratory has recently reconstructed various objects buried inside multilayer soils using deep learning-based signal processing. For the current study, a neural network is being trained on simulated datasets of real bridge and building structures to detect internal anomalies that are difficult to detect with conventional signal processing. Experimental validation will be performed in collaboration with the Earthquake Engineering Laboratory at the University of Nevada, Reno, which provides small-scale bridge structures for real measurements. The combination of multimodal SDR-based sensing and deep learning post-processing demonstrates the ability to accurately detect subsurface features and embedded defects for structural health monitoring. Though these findings reflect controlled experimental conditions, future work will extend this approach to more complex real-world structural environments.

sciforum-180513: FBG thermo-mechanical monitoring of airport rigid pavement infrastructures

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At the present state-of-the-art, airport engineers deploy strain and temperature structural health monitoring (SHM) systems to continuously investigate pavement rheological behaviour throughout its service life. Despite the high resolution and accuracy of strain gauges and thermocouples, the high electromagnetic interference, durability issues and disjoint measuring principles pose significant challenges to a long-term pavement SHM system.

Contextually, preliminary fiber optic sensor applications demonstrate promising simultaneous thermal and strain reading capabilities, maintaining good stability throughout time. Therefore, a comprehensive effort is required to establish the measurement reliability of these sensors in current pavement experimental frameworks. In particular, this work aims at validating Fiber Bragg Grating (FBG) optic sensors in pavement thermo-mechanical monitoring under static conditions. First, the sensors are tested in a simple supported fiberglass beam under uniformly distributed load and compared with an equivalent finite element model. Then, a scaled concrete plate is instrumented, subjected to simple support bending due to point load testing and later verified against finite element analysis (FEA). Distinctly, the same specimen undergoes positive and negative static thermal loading inside climate chamber, in comparison with concrete analytical thermal expansion and contraction. Finally, FBG sensors embedded in concrete beams are tested under mechanical and thermal conditions against FEA results. In conclusion, FBG sensors provide a feasible alternative to traditional sensing of strain and temperature of rigid pavement, showcasing robust multiplexing and consistent measurements against numerical models at the different experimental scales explored.

sciforum-172228: Material Degradation and Defect Assessment in Beam Structures Using Mechanical Responses

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Structural health monitoring (SHM) methods are widely used to detect defects in aeronautical, civil, and mechanical engineering structures. Structural defects may occur due to crack initiation and propagation, fatigue damage, or deterioration of structural connections. The growth of such defects can lead to catastrophic failures or mechanical breakdowns. Therefore, early detection of defects is essential to prevent structural failure. A typical normalization approach is applied to normalize the dynamic response measurements, including natural frequencies and mode shapes. These vibration measurements are obtained from measured input–output data during modal parameter estimation of the structure. In the present study, normalized vibration measurement parameters are utilized for defect detection. The proposed methodology is based on calculating the normalized ratio of natural frequencies obtained from intact and defected finite element (FE) models of beam structures. These normalized ratios are employed to localize damage within the structure, while defect size estimation is performed using the damage ratio derived from comparisons between intact and damaged states. Various defect cases are investigated using the normalized natural frequency ratios. Several numerical procedures are carried out to evaluate the applicability and effectiveness of the proposed method. Damage localization is achieved by analyzing normalized frequencies across different segmented defect zones of the beam. Furthermore, defect magnitude is estimated by correlating normalized natural frequency variations with the percentage of damage severity.

sciforum-181752: Non-destructive testing and detection of electro-thermal damage in carbon fibre reinforced composites under fault-representative conditions

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The reliance of modern aircraft development on Carbon Fibre Reinforced Plastics (CFRP) composites amounts up to 50% of an aircraft's total component structure offering high strength-to-weight ratio, corrosion resistance, and superior fatigue performance. The parallel integration of CFRP structures within more electrified aircraft architectures introduces new potential failure modes (Rail-to-ground and high-impedance fault conditions) associated with unintended electrical current flow through structural components. However, CFRP's electrical response, consequent electrical degradation from joule heating and residual structural integrity is poorly understood, leading to over-engineered solutions ensuring that CFRP is kept separate from conducting channels. This research develops a diagnostic framework that integrates ultrasonic Non-Destructive Evaluation (NDE) and destructive mechanical tests, with varied electrical loading conditions for the detection and characterization of electrical degradation in aerospace-grade CFRP. In this study, quasi-isotropic carbon-fibre/epoxy laminates were subjected to controlled electrical currents of up to 7 A, raising local temperatures to 20°C below and above the glass transition temperature (T_g) of the polymer matrix. Real-time infrared thermography monitored temperature during conduction. Post-conduction Phased Array Ultrasonic Testing (PAUT) and micro-CT were deployed to assess thermal damage relative to T_g. Robotic PAUT was employed to acquire spatially registered volumetric data of CFRP, reconstructing time-resolved A-scans into B-scan slices and a 3D ultrasonic volume. These measurements were correlated with micro-CT, electrical resistance, destructive characterization, and visual observations. Initial NDE results indicate that ultrasonic methods are sensitive to early-stage subsurface degradation due to conduction of electrical fault current. Mechanical testing further confirms a reduction in interlaminar strength in affected regions.

sciforum-180219: Potential of Satellite Remote Sensing for Flexible Pavement Monitoring

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Introduction

The functionality and safety of road networks depend on the structural integrity and surface conditions of flexible pavements. During their lifetime, pavements undergo progressive deterioration due to environmental exposure and traffic loads, requiring continuous monitoring to ensure effective maintenance planning. Traditional inspection techniques, such as visual surveys and in situ testing, are often labor-intensive, expensive, and limited to localized measurements. In the context of non-destructive testing (NDT) for structural health monitoring, satellite remote sensing offers a promising approach for large-scale assessment of pavement conditions.

Methods

This study investigates the possibility of using multispectral and hyperspectral satellite imagery to monitor the aging phenomenon of flexible pavements. The methodology is based on the analysis of surface reflectance variations in the visible (VIS), near-infrared (NIR), and shortwave infrared (SWIR) spectral regions. In fact, in these regions, variations in asphalt reflectance spectra are directly associated with material aging, oxidation, asphalt content reduction and aggregate exposure. Changes in the spectral signature were also evaluated using literature spectral indicators such as the VIS2 index (830–490 nm).

Results

The results indicate that pavement aging is associated with a general increase in surface reflectance and characteristic changes in spectral absorption features. In particular, the loss of hydrocarbons leads to the disappearance of absorption bands near 1700 nm and 2300 nm, while aggregate exposure and oxidation generate features around 520, 670, and 870 nm. Due to technical limitations related to the low spatial resolution of satellite sensors, a preliminary case study was conducted on airport pavements, confirming the capability of satellite spectral products to detect aging-related variations.

Conclusions

Despite the limited ground resolution characterizing most optical satellites, Satellite remote sensing demonstrates strong potential as a complementary NDT technique for structural health monitoring of flexible pavements, enabling large-scale, repeatable, and long-term assessment of pavement conditions.

sciforum-183560: Proper Reporting of Guided Wave Structural Health Monitoring:Per-Indication Documentation, Calibrated Reflection Coefficient, And Mode Confirmation In Magnetostrictive Sensor Pims Reports

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Magnetostrictive sensor (MsS) permanently-installed monitoring systems (PIMS) provide long-range guided wave structural health monitoring for buried, insulated, and inaccessible pipelines using the nondispersive T(0,1) torsional mode. While the physical performance of MsS PIMS — including high spatial resolution, multi-frequency operation, and calibrated signal amplitude — represents a significant technical advantage over competing technologies, the reporting of GWT monitoring data has not kept pace with the technical capabilities of the method. Three systematic reporting gaps are identified and examined: (1) the absence of per-indication report pages, which leaves clients without dedicated documentation for each monitored feature; (2) the presentation of monitoring amplitude data without a physically calibrated y-axis in units of reflection coefficient; and (3) the absence of spectrogram evidence for T(0,1) mode confirmation and dispersion curve analysis on a per-indication basis. This paper describes the extension of the per-indication reporting framework introduced in GIM (Guided Wave Inspection and Monitoring) software v7.0 for pipeline inspection to the GWT structural health monitoring workflow. A three-phase field installation on a 12.75-inch-OD, 0.700-inch-wall buried FBE-coated pipeline demonstrates both the current GIM v6 reporting practice and the specific elements that remain outside the report under that practice: dead zone artifact identification, mirror reflection analysis, and the T(0,2) cut-off frequency analysis (91.39 kHz for the 0.700-inch wall) that explains frequency selection. The post-installation baseline report was assessed by a senior technical reviewer as excellent — yet none of the physically essential per-indication elements are embedded in it. The improvements enabled by GIM v7.0 are argued to be a necessary step toward the documentation standards expected from structural health monitoring programs in the pipeline industry.

sciforum-181990: PZT-Based Structural Health Monitoring of a Retrofitted RC Frame Structure with Vertical Greenery Systems

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Worldwide, a significant portion of the building infrastructure is aging and requires urgent assessment and retrofitting to meet modern provisions and sustainability standards. This issue is particularly critical in seismically active regions, where a significant part of the existing building stock consists of reinforced concrete (RC) structures that were designed according to outdated seismic codes. At the same time, modern cities are increasingly adopting energy renovation and green retrofit strategies, including vertical forest (VF) renovations. Consequently, there is an extended need for applicable Non-Destructive Testing (NDT) methods to evaluate the severity of damage in RC structures. In this context, Structural Health Monitoring (SHM) techniques could constitute an effective response to these demands to avoid sudden collapses and to support the development of targeted and well-designed plans for repairing and retrofitting strategies, expanding the lifespan of RC structures. Specifically, the Electromechanical Impedance (EMI) method, based on the electromechanical coupling of PZT sensors, has proven to be highly sensitive to changes in the mechanical properties of structural elements. Within this framework, the present study investigates the integration of VF renovation, including structural interventions, with SHM technologies. Therefore, shake table experiments were conducted on an RC frame structure before and after structural strengthening, with PZT installed at key structural locations. The experimental outcomes demonstrate the applicability and the effectiveness of the proposed method in detecting damage in RC frame structures subjected to earthquake excitations.

sciforum-183538: Seismic retrofitting and performance evaluation of exterior-reinforced concrete joints with C-FRP ropes

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The inherent fragility of beam–column joints necessitates the retrofitting of existing reinforced concrete structures. However, the effectiveness of such interventions—especially when synthetic reinforcement is employed—may be limited by brittle failure modes and premature debonding. Non-destructive testing methods, such as the electromechanical impedance (EMI) technique, offer a promising approach for early damage detection and structural assessment. This study investigates the combined application of Carbon Fiber-Reinforced Polymer (C-FRP) rope retrofitting and piezoelectric-based structural health monitoring for real-scale beam–column joints. A novel wireless impedance–admittance monitoring system (WiAMS) is employed to capture the response of externally bonded PZT transducers, enabling damage identification through induced variations in electromechanical impedance of PZT sensors. Experimental results from incremental cyclic loading tests, with up to 5% story drift, demonstrate that the proposed retrofitting scheme significantly enhances the seismic performance of beam–column joints. Furthermore, the PZT-based structural health monitoring system effectively tracks load-induced damage and structural degradation of real-scale beam–column joints in real time. The findings of this study highlight the potential of PZT-based monitoring to evaluate the efficacy and performance of retrofitting schemes. Thus, the integration of smart materials and novel monitoring technologies with advanced retrofitting techniques can enhance the resilience and reliability of existing reinforced concrete structures.

sciforum-181777: Waveguide Effects in Structural GPR Data: Numerical Insights

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Ground-penetrating radar (GPR) is extensively used in structural engineering for the non-destructive evaluation of materials such as concrete and masonry. However, high-frequency GPR data often exhibit complex signal signatures that cannot be fully explained by conventional specular reflection-based assumptions. This study provides numerical insights into waveguide effects in structural GPR data, highlighting their role in generating non-intuitive responses, contributing to signal interpretation and translating them into novel diagnostic tools rather than mere signal interference.

Numerical simulations of structural configurations were conducted to reproduce electromagnetic wave propagation. The results demonstrate that, for specific combinations of geometry, material properties, and antenna frequency, structural components can behave as waveguides, promoting horizontal propagation of electromagnetic energy along layers, and interfaces. The study proves that waveguide effects can enhance GPR side visibility and provide, in specific cases, velocity estimation of the top structural layer.

To support the numerical findings, simulated responses were compared with real GPR datasets acquired from representative structural case studies, revealing strong agreement in observed signal behaviour and confirming the physical relevance of the identified mechanisms.

The study emphasizes the importance of recognizing waveguide-induced propagation in the interpretation of GPR data. By integrating numerical modelling with field observations, it contributes to improving the reliability of structural diagnostics and reducing the risk of misinterpretation in engineering assessments.

Session 6. NDT for Additive Manufacturing

sciforum-182007: Birefringent properties of 3D printed and other polymers

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Birefringence describes the optical properties of optically anisotropic or chiral materials. Linear birefringence is defined as the difference between the refractive indices of the extraordinary and ordinary ray direction, i.e., $\Delta n = n_e - n_o$, and proportional to the optical path difference. Circular birefringence, on the other hand, occurs in chiral materials and describes the rotation of the plane of polarization.

As linear birefringence is a measure of anisotropy in the structure of a glass or a polymer, stress induced in glasses or polymers can be measured by stress birefringence. Interestingly, this effect can also be found in 3D printed materials, such as fused deposition modeling (FDM)-printed models of different layer orientation and thickness [1], or stereolithography (SLA)-printed objects containing liquid crystals or nanofibers [2,3].

Here we report birefringence measurements on 3D printed translucent objects after different curing / thermal post-treatments, performed using a microscope with crossed polarizers as well as large-scale crossed polarizers, to measure linear and circular birefringence. These measurements can be extended to other polymeric objects, such as foils in solar panels or bulletproof glass, to investigate material aging in addition to residual stress.

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sciforum-179337: Effect of Layer Orientation on Fracture Dynamics Using a 3D Image Construction Technique

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Layer orientation is a critical parameter in the additive manufacturing method. This process parameter significantly influences the material's mechanical behavior and fracture mechanics. In this study, we investigated the effect of layer orientation on fracture dynamics using a three-dimensional (3D) image reconstruction approach based on the Depth from Defocus (DFD) technique. The DFD method was employed to capture high-resolution defocused image sequences that enable building an accurate reconstruction of surface topology and evolving crack geometry in three dimensions. The specimens contain numerous voids formed during the AM fabrication process and dynamic high-strain-rate impact. The voids play a pivotal role in the specimen's crack propagation mechanics.

Objective: The research aims to develop an understanding of the presence of voids in the tension and compression zones of a fractured specimen.

Method: The test specimens were produced by a selective laser melting process in the metal additive manufacturing method for an AlSi10Mg, aluminum alloy. There were two layer orientations used, such as horizontal and vertical layer direction, for making the specimens at a global energy density of 37.1 J/mm^3. The specimens were prepared according to the ASTM A370 Charpy V-notch standard. The fracture in the specimen was created by the Charpy testing, and the Charpy-tested specimens were investigated to understand the fracture dynamics of the materials. There were three zones identified in the fracture surface of the tested specimens: tension, neutral, and compression (as Type - I fracture mechanics), using a box counting method. The voids of the three zones were studied by using a digital microscope and the DFD method. The collected data were analyzed using statistical methods.

Finding: The layer orientation has an effect on the void quantity and size in the tension and compression zones of the specimens.

sciforum-181172: Influence of Remaining Support Structures on the Ultrasonic Testing of Additively Manufactured Components

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In additive manufacturing, support structures are required to stabilize overhangs and ensure the geometric accuracy of components. However, their design represents a trade-off: while delicate structures facilitate easier removal after the build process, they limit heat dissipation during fabrication. Variations in support structure design therefore affect local heat transfer, leading to differences in residual stresses, microstructure and surface quality.

As these effects can also influence the results of non-destructive testing methods, understanding the impact of support structures on ultrasonic testing (UT) is of particular interest. Performing UT directly on components with intact support structures offers the advantage of enabling early quality assessment without time- and cost-intensive post-processing. This allows potential manufacturing defects to be detected prior to component removal, significantly increasing the efficiency of quality assurance in additive manufacturing.

In this work, the influence of different support structure designs on the reflection behavior of ultrasonic waves is investigated using both experimental and numerical approaches. In addition to ultrasonic measurements, simulation-based models are employed to analyze sound propagation and reflection within regions containing support structures. The aim is to evaluate to what extent reliable ultrasonic testing can be performed without prior removal of the support structures in practical industrial applications today.

sciforum-183332: Non-destructive technique for determining the elastic properties in carbon-reinforced polymer laminates using modal frequencies

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This work presents a non-destructive technique for determining the elastic properties in carbon-reinforced polymer laminates using modal frequencies. The proposed method combines data from vibration tests with finite element modeling and global optimization. The purpose of the study is to identify the elastic moduli and Poisson's ratios of orthotropic materials from vibration tests and compare them with some static tests. In the first stage, a design-of-experiments approach is used to construct a plan that includes the elastic properties of the composite lamina. Then, using the ANSYS software package, each design point is analyzed to determine the natural frequencies and mode shapes of the rectangular plate. In the second stage, response surface models are developed to approximate the structural behavior of the composite plate. In parallel, the natural frequencies and mode shapes of a free rectangular composite plate are obtained from experiments using POLYTEC equipment. In the final stage, the material properties are identified by minimizing the error between the numerical and experimental frequencies. Additionally, the elastic modulus of the composite specimens is determined from static tensile tests and compared with the values obtained from the dynamic identification procedure. The results show that the material properties obtained from vibration and static methods may differ. Therefore, this method should be regarded as a partial identification approach, focused on the most significant parameters from a dynamic perspective.

Session 7. NDT in Cultural Heritage Preservation

sciforum-182129: Advanced GPR Data Interpretation for the Diagnostic of Buried Historical Road Tracks: Case Studies from Ancient Rome

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Historic roads are integral to the cultural and visual heritage of landscapes, reflecting the historical narratives of the regions they served. Mapping the planimetric and altimetric geometry of these routes provides insights into past human interactions and supports applications such as sustainable tourism and "slow mobility" [1]. However, detecting buried historical tracks remains challenging due to heterogeneous subsurface conditions and complex electromagnetic wave propagation. In common-offset Ground Penetrating Radar (GPR) surveys, the absence of a reliable velocity model introduces significant uncertainty, often resulting in ambiguous radargrams where meaningful features are difficult to distinguish from noise [2].

To address these challenges, this study proposes a scalable diagnostic framework for the interpretation of buried infrastructure. The methodology extends conventional time-domain analysis by applying Short-Time Fourier Transform (STFT) to obtain localised spectral representations of GPR signals. Key attributes, including central frequency and spectral energy are extracted to characterise material-dependent responses that are not evident in raw data.

The novelty of the approach lies in its ability to provide a systematic and transferable workflow that enhances interpretability without requiring detailed velocity models, making it suitable for complex and heterogeneous environments.

The framework is validated through archaeological case studies in Rome, including investigations at Villa dei Sette Bassi, where historical evidence suggests the presence of previously undocumented road connections. The results demonstrate clearer delineation of subsurface features, enhanced contrast between archaeological remains and surrounding materials, and improved discrimination between structural responses and noise.

These findings highlight the potential of frequency-domain GPR analysis as a robust and objective approach for reducing interpretational ambiguity in the detection of buried historical road networks.

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sciforum-181939: High-Resolution GPR Diagnostics for Historical Wall Paintings: A Case Study of Giotto's Paintings in Florence

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Wall paintings have a very long history, and during the Renaissance, paintings were mainly used in religious buildings. With time, the paintings are increasingly vulnerable to physical and environmental degradation. Effective preservation requires detailed knowledge of the state of conservation of wall surfaces to guide operational decisions. Traditional GPR applications in this field are often hindered by the limited thickness of plaster and the complexity of near-surface features. This occurs because the pulse width at standard frequencies often exceeds the layer thickness, causing the surface reflection to mask the targets. In the Bardi Chapel (Basilica of Santa Croce), Giotto's XIV-century murals depicting the life of St. Francis are currently undergoing a restoration campaign conducted by the Opificio delle Pietre Dure. During the restoration, a GPR framework was used to characterize the plaster layers that support these paintings. By employing a non-invasive NDT approach based on electromagnetic wave propagation, the research provides a high-resolution 2D and 3D imaging solution to detect internal defects without compromising the integrity of the historic material. Considering the limited thickness of the plaster and painted layers, the tests were conducted using the C-Thrue XS, a high-resolution GPR antenna with a 2 GHz central frequency with crossed polarization. This setup is designed to enhance the visibility of subtle internal anomalies while ensuring the physical integrity of the fragile surface. During data acquisition, a transparent sheet of paper was placed over the painting to prevent contact between the GPR antenna and the painted surface. This study aims to address these limitations, applying advanced GPR processing and interpretation strategies for improving the detection and characterization of surface defects and possible material heterogeneities in the wall. By optimizing the antenna's performance and data interpretation strategies, the framework provides a robust tool for the non-invasive monitoring of fragile murals.

sciforum-181770: Integrating Non-Destructive Testing with HBIM for the Preservation of Timber-Framed Masonry Heritage Structures in Switzerland

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Introduction:

Advancing data-driven conservation of Switzerland's timber-framed masonry heritage requires a framework that unites non-destructive diagnostics with digital modeling for predictive preservation. While non-destructive testing (NDT) techniques such as ultrasonic testing, infrared thermography, and ground-penetrating radar are increasingly applied, their potential remains limited by fragmented workflows and insufficient integration with Historic Building Information Modeling (HBIM) environments. This study presents a novel framework integrating NDT data into HBIM, establishing a scalable, forward-looking strategy for proactive, data-driven heritage conservation and demonstrating early-career research innovation in smart heritage management.

Methods:

A structured literature review identifies limitations in current NDT applications and HBIM-based heritage modeling. Based on these insights, a conceptual workflow is developed for multi-source NDT data acquisition, semantic enrichment, and fusion within HBIM. Interoperability standards are leveraged to enable consistent mapping of heterogeneous diagnostic data, supporting visualization, anomaly detection, and condition assessment in a unified digital environment.

Results:

Analysis shows that current practices underutilize NDT data due to inconsistent integration. The proposed framework demonstrates how structured NDT-HBIM integration enhances visualization, condition assessment, and predictive monitoring, improves diagnostic accuracy, reduces manual interpretation, and provides actionable insights for conservation planning.

Conclusions:

This study establishes a pathway toward digitally enabled heritage preservation, bridging NDT, HBIM, and digital twin concepts. By formalizing data integration and visualization workflows, the approach provides a scalable, novel, and practical strategy for informed conservation, while enabling predictive diagnostics and proactive heritage management. The framework highlights early-career research leadership and positions the study at the forefront of smart heritage diagnostics.

sciforum-181789: Interpretable Non-Destructive Discrimination of Japanese Bast Fibers via Micro-Hyperspectral Imaging

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Accurate paper fiber identification is essential for cultural heritage conservation to select appropriate repair materials. However, conventional methods are often destructive, and macroscopic data-driven approaches lack physicochemical interpretability. This study introduces a non-destructive, interpretable approach to discriminate three traditional Japanese bast fibers (Kozo, Mitsumata, Gampi) using micro-hyperspectral imaging (Micro-HSI) combined with chemometric analysis.

Using well-documented, undyed, single-raw-material samples from an authenticated archive, we established baseline spectral characteristics. Reflectance spectra from microscopic regions were collected in the 400–1000 nm range. Data were preprocessed using Savitzky–Golay first derivative filtering and Z-score normalization to mitigate baseline drift and intensity variations.

While principal component analysis (PCA) yielded limited separation due to the fibers' similar cellulose compositions, linear discriminant analysis (LDA) achieved clear classification. LDA highlighted subtle spectral differences, with key discriminative features linked to visible-range baseline variations, lignin-related absorption (400–450 nm), and near-infrared O–H and C–H overtone vibrations (~835 nm).

As this is currently a feasibility study, the model relies on pristine samples. Future work will expand the dataset to include aged, mixed-fiber, and geographically diverse papers, incorporating additional preprocessing methods like standard normal variate (SNV) to enhance robustness. These findings validate Micro-HSI as an effective, non-destructive tool for fiber identification, providing a crucial baseline for the future conservation of historical paper artifacts.

sciforum-183521: Leveraging machine learning for the automated identification of cultural heritage materials via external reflectance FTIR spectroscopy

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External reflectance Fourier-transform infrared (ER-FTIR) spectroscopy is a key non-destructive archaeological analysis tool. However, the resulting spectra are often distorted by surface scattering and complex reflectance backgrounds. This study presents an automated machine learning pipeline designed to classify mineralogical and organic samples with high diagnostic precision. Leveraging a dataset of 189 diverse samples, a robust Random Forest (RF) classifier integrated with advanced chemometric preprocessing is effectively implemented. Specifically, the application of a first-order Savitzky–Golay derivative and regional spectral slicing (1800–400 cm^{-1}) is evaluated against raw intensity models. The optimized pipeline achieves a significant overall accuracy matching human expert performance benchmarks. Key findings demonstrate substantial diagnostic power for organic binders or coatings and silicate groups. Furthermore, it successfully isolates characteristic vibrational inflections such as Si-O-Si stretching and Carbonyl overtones from complex backgrounds. However, heterogeneous unclassified category materials present challenges due to high chemical variance. The model proves to be reliable for the identification of primary archaeological materials. This methodology enables the field identification of diverse materials, such as silicate-based pigments (e.g., distinguishing between lapis lazuli, kaolinite, and orthoclase via Si-O-Si stretching), carbonates like calcite or marble in sculpture, and complex polymineralic rocks such as granite or breccia. This technique enhances characterization clarity by isolating subtle diagnostic chemical footprints that are typically obscured by surface scattering and complex background distortion. The integration of derivative-based preprocessing with ensemble learning provides a scalable and objective framework for real-time field identification. This AI-driven approach enhances the speed and consistency of cultural heritage conservation and material characterization by reducing the over-reliance on manual expert interpretation in the field.

Session 8. Data Fusion and Integration

sciforum-181852: Low-Cost Embedded Multiview Stereo Vision System for Plant Phenotyping

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The measurement of phenotypic variables in plants is a fundamental process for growth characterization, assessment of physiological state, and decision-making support in agricultural systems. Traditionally, this process has been labor-intensive, as it relies on manual measurements or high-cost instrumented systems, limiting its applicability in continuous monitoring scenarios. In this context, this work presents a low-cost, low-power, non-destructive methodology based on an embedded ESP32-CAM system for image acquisition and the estimation of phenotypic variables using multiview stereo vision and computer vision techniques. The proposed system is designed to provide an accessible alternative for in-field visual data acquisition and processing without physically altering the plant structure. A multiview stereo vision configuration composed of two ESP32-CAM modules is employed, enabling depth estimation through disparity computation. This approach allows the recovery of spatial information from image pairs. The methodology is based on feature extraction and geometric modeling, establishing relationships between image-based measurements and the actual dimensions of the plants. The proposed approach enables the non-destructive estimation of structural variables, such as height and volume, using low-cost hardware. The accuracy of these measurements is assessed through comparison with ground truth data, validating the system's suitability for accurate and reliable implementation in plant phenotyping applications.

sciforum-181873: Sensor-Based Frameworks for Predictive Condition Monitoring and Operational Assessment

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The growing complexity of industrial systems, particularly in discrete manufacturing and assembly environments, has increased the need for monitoring approaches capable of identifying degradation before critical failures occur. Traditional non-destructive testing (NDT) frameworks primarily focus on machines and structural components, often overlooking human operators whose performance variability, workload, and environmental exposure influence system reliability. Within the NDT 4.0 paradigm, this study proposes a sensor-based conceptual framework that integrates human factors with mechanical components in a unified operational assessment structure. The framework incorporates multi-modal sensing technologies, including wearable, environmental, vibration, and acoustic sensors, to capture real-time signals of equipment condition and human operational states. These heterogeneous data streams are fused within a data integration layer to generate a unified operational health index. A layered architecture structures the framework into four stages: data acquisition, preprocessing, feature extraction, and predictive assessment. Sensor data are analyzed to identify anomalies and deviations from baseline operational signatures associated with early-stage degradation, including mechanical faults and operator-related conditions such as fatigue, repetitive strain, and environmental stressors. To demonstrate practical applicability, the framework is contextualized within an automotive assembly workstation, where operator fatigue indicators are integrated with vibration and acoustic signals from assembly tools to support early detection of operational risks. By incorporating human–system interactions into predictive monitoring, the framework enhances operational reliability, supports preventive maintenance planning, and strengthens safety management in industrial environments undergoing digital transformation.

sciforum-182005: Using deep learning to enhance eddy current system transfer functions

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An eddy current system transfer function, which converts between the impedance output of simulation and the voltage output of commercial systems, is a common use of transfer functions in nondestructive testing. Normally, transfer functions are for specific settings on the commercial equipment. Any change to certain settings such as gain or drive voltage results in the transfer function no longer being valid. This creates an issue with NDT 4.0, with the integration of digital engineering and nondestructive testing. This issue becomes larger when trying to account for settings changes with normal regression techniques. This is because the internal circuitry of the commercial systems contains proprietary data processing and physical circuitry components. A deep learning approach was used to develop a system transfer function using basic MATLAB tools for bidirectional conversion between complex impedance and complex voltage that accounts for the change in settings. The settings accounted for are gain, drive, and frequency. Rotation can be accounted for in pre and post processing depending on the direction of the conversion. The system transfer functions showed high accuracy within trained frequencies with both trained and novel drive and gain values when converting from complex voltage to complex impedance. A simple linear interpolation of predicted values at novel frequencies achieves the same high accuracy within novel frequency settings. The inverse transfer function showed high accuracy within trained frequencies, drive and gain values, but struggles to predict commercial system measurements in untrained regions. This novel enhanced system transfer function has high potential impact in the application of model-assisted probability of detection, supplemental data-assisted probability of detection, settings optimization for enhanced probability of detection, digital twins, and other enhanced digitally integrated predictive capabilities in nondestructive testing.

Session 9. Early Career Researcher Session

sciforum-182006: Digitalising Acoustic Data: An Extended Reality Framework for the Visualisation of Simulated Sound Dispersion in the Ancient Roman Theatre of Palmyra

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Acoustic reconstruction is crucial for understanding the functional and historical identity of heritage spaces, as it enables the analysis and representation of their acoustic behaviour. Many historical environments, especially performance and religious spaces, were designed with acoustic considerations in mind, making their sonic features a key aspect of their heritage significance. However, such complex acoustic dynamics are not adequately captured by traditional documentation methods, such as drawings and digital surveys, including photogrammetry and laser scanning. [1].

Recent trends in archaeoacoustics have used immersive technologies to represent and analyse acoustic phenomena within historical environments [2]. While high-fidelity acoustic simulations can capture detailed acoustic data, communicating these complex spatial characteristics to stakeholders remains a challenge.

This study contributes to the digitisation of Non-destructive Testing (NDT) data by proposing a stakeholder-centred extended reality (XR) framework for visualising and communicating acoustic information obtained from digital heritage architecture. As an early-stage research initiative, it investigates how XR environments can support intuitive understanding of visualised acoustics through interactive and immersive representations.

A three-dimensional digital model of the Roman Theatre of Palmyra, Syria, a UNESCO World Heritage Site, was refined, and room acoustic simulations were performed to generate visual representations of sound distribution, illustrating the theatre's performance under varying source and receiver configurations. The simulation model was then used to auralise the theatre, adding an extra sensory dimension to the simulation. These simulated outputs were integrated into an XR environment, enabling interactive exploration of the theatre's acoustic features through a combination of visual, spatial, and audio representations.

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sciforum-181840: Evaluation of Acoustic Emission Energy Trend in Small-diameter Concrete Core with Large Size Coarse Aggregate under Compression Stress Field

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Concrete cores extracted from mass concrete dams are typically larger in diameter relative to the nominal maximum aggregate size than cores taken from conventional structures. As a result, individual coarse aggregates within a core specimen may span a substantial fraction of the cross-section. This geometric mismatch complicates mechanical characterisation and the interpretation of fracture behaviour under compressive loading, both of which are governed by the internal aggregate structure. Acoustic emission (AE) monitoring offers a non-destructive method to track damage evolution in real time, as the AE energy released during loading reflects the progressive initiation and coalescence of cracks. Fitting a logistic curve to the cumulative AE energy trend allows the loading history to be decomposed into distinct crack-progression stages. Where aggregate gradation is broad and heterogeneous, a model accommodating multiple successive stages may be required, and the Akaike Information Criterion (AIC) provides a quantitative basis for selecting the appropriate model complexity. X-ray computed tomography independently enables the internal aggregate structure to be visualised and quantified in terms of geometric indices such as size, area, and shape, without mechanical intervention. Comparing these geometric indices against the fitted logistic parameters then offers a means of understanding how aggregate geometry affects crack initiation and propagation.

This study applied both two-stage and three-stage logistic models to the cumulative AE energy curves of concrete cores taken from a concrete dam, selected the better-fitting model for each specimen using the AIC, and examined correlations between X-ray CT-derived coarse aggregate geometric indices and the resulting logistic parameters. Aggregate size indices were significantly and positively correlated with the relative contribution of the final crack-progression stage, while specimens containing vertically elongated aggregates tended to show an earlier onset of intermediate cracking, consistent with strain concentration along the loading direction at aggregate–mortar interfaces.

sciforum-181838: Finite Element Simulation of Compressive Fracture Behavior for Concrete Core incorporating X-ray CT-Based Material Phase Modeling

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Concrete is a primary construction material for infrastructure; however, the progression of internal damage is difficult to estimate due to its nonlinear mechanical behavior, especially under compression stress. FEM-based simulation has been investigated as an approach to this issue; simulation accuracy is significantly influenced by the material phase distribution and material properties assigned to the model. In this study, X-ray computed tomography (CT)-based modeling is applied to simulate the compressive fracture behavior of concrete cores. The effects of material phase distribution and material properties on simulation accuracy are evaluated.

Testing concrete core samples were collected from an in-service irrigation structure in Japan. X-ray CT scanning was performed for concrete cores. The CT images are segmented into five material phases: background, cracks, voids, aggregates and mortar. Finite element meshes are generated from the segmentation data with the interfacial transition zone (ITZ) between aggregates and mortar defined as a separate phase. Compressive fracture simulations are conducted using software, with appropriate material models assigned to each phase. In addition, the influence of the presence of cracks, ITZ, and voids on simulation accuracy is examined by comparing models with and without these phases.

Thus, the deteriorated pier exhibits the highest crack volume fraction, while the less-damaged pier shows the lowest void fraction, indicating higher material density. These trends are consistent with observations on the physical core samples, demonstrating that X-ray CT-based mesh generation has the potential to reproduce material phase distributions with high fidelity. Furthermore, it is indicated that the presence of cracks and ITZ, as well as the assigned material properties, substantially affect simulation accuracy, highlighting the importance of appropriately defining material phase distribution and material properties in FEM-based fracture simulations.

sciforum-181441: A Robust Numerical Framework for Ultrasonic Wave Characterization in Complex Petrophysical Environments

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Characterizing internal rock heterogeneities, such as pores, vugs, and micro-fractures, represents a fundamental challenge in petrophysics and reservoir engineering. This study presents a robust numerical framework based on the k-space pseudospectral method (k-Wave) to model 1 MHz ultrasonic wave propagation within complex petrophysical environments. A heterogeneous rock model was developed, consisting of a fluid-saturated host matrix with a longitudinal velocity of 2500 m/s, embedded with five discrete circular inclusions assigned a lower velocity of 350 m/s to simulate high-contrast impedance mismatches typical of vuggy porous media. The wave propagation was excited using a 51-element linear source array, and the resulting steady-state acoustic field was analyzed using a 16384-point Fast Fourier Transform (FFT). The simulation results revealed significant scattering effects, wavefront distortions, and the formation of pronounced acoustic shadow zones behind inclusion clusters. Quantitative evaluation was performed using several key metrics, including a Contrast Ratio (CR) of 3.51 dB and an effective attenuation coefficient of 421.95 dB/m, which reflect the combined influence of intrinsic absorption and extrinsic scattering. The stability of the framework was further enhanced by integrating the Convergent Born Series (CBS) protocol and fractional viscoacoustic modeling to account for frequency-dependent power-law absorption. Crucially, a comparative validation between the k-Wave results and the Modified Born Approach (MBA) showed a numerical discrepancy of less than 1%, confirming the high precision of the proposed model. This framework provides an accurate and computationally efficient tool for interpreting ultrasonic testing data, facilitating the non-destructive estimation of porosity and inclusion density in heterogeneous porous media.

sciforum-181786: Combining GPR and Magnetic Data through the Integration of Microwave Tomography (MWT) and Depth from EXtreme Points (DEXP)

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In subsurface investigations, it is common practice to employ multiple Non-Destructive Testing (NDT) techniques in order to gather as much information as possible about the area under study. The concept of “data integration” arises from the need to combine these different datasets in order to obtain more insights than those obtained from any single dataset, thereby enhancing information content and reducing interpretative ambiguities.

Among the different NDT techniques, this study focuses on Ground Penetrating Radar (GPR) and magnetic methods. The former is an active technique sensitive to dielectric permittivity, whereas the latter is a passive method sensitive to contrasts in magnetic susceptibility. These two NDT methods, despite being fundamentally different, are often used together for several applications, allowing for the detection of buried targets through the analysis of electromagnetic and magnetic anomalies occurring within the investigated area.

Moreover, beyond standard processing and filtering procedures, both methods benefit from advanced imaging techniques, such as Microwave Tomography (MWT) for GPR and Depth from EXtreme Points (DEXP) for magnetic methods, which allow further information to be obtained for the detection and localization of subsurface targets.

In this study, we present an approach for the quantitative integration of GPR and magnetic data based on combining the results obtained from their respective MWT and DEXP imaging techniques, yielding a single composite result that enhances the interpretability and improves the characterization of the subsurface. The reliability of the proposed approach was validated through its application to simulated GPR and magnetic data for a reference scenario, as well as to a real-world environmental scenario. In both cases, the integrated results outperform the individual methods, enabling more accurate subsurface models.

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sciforum-181856: Fault Diagnosis of Rotating Machinery using Infrared Stress Method with Deep Learning

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Rotating machinery used in industrial applications is designed to withstand the various stresses during operation. When wear or damage causes a failure during operation, the faulty component must be found quickly. Failing to detect a failure can disrupt the smooth formulation of repair plans, leading to increased downtime and higher maintenance costs. Methods for understanding stress distributions in rotating machinery and performing fault diagnosis include strain gauge analysis and vibration analysis. These conventional methods have a long history of research and are well established. However, measuring spatial stress distributions in rotating machinery is difficult due to complexity. To address these limitations, we propose diagnosis method for rotating machinery using infrared cameras. Infrared cameras offer a non-contact and non-destructive condition monitoring method capable of recording temperature distributions over a wide area. Therefore, this method is suited to capture spatial stress distribution. In field situations, however, an emissive distribution of the rotation axis varies within painting conditions. Therefore, there is a need for technology that enables the use of infrared cameras for fault diagnosis of actual rotating machinery. The objective of this study is to capture images of the surface of the rotating shaft of actual rotating machinery using an infrared camera and to predict the results of vibration measurements performed on the same target.

sciforum-181819: Interpreting Spatial GPR Classifications in Urban Trees Using Aggregation Strategies

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Urban environments increasingly rely on trees as key components of climate adaptation and liveability strategies, while also requiring careful management of their interaction with subsurface infrastructure. Ground Penetrating Radar (GPR) is widely used to investigate shallow subsurface conditions and detect tree root systems. However, translating spatially distributed geophysical observations into forms that can support consistent interpretation at asset level remains a key challenge in practice.

Building on a previously developed framework, GPR data are segmented into repeatable spatial units within the root zone of individual trees, including common urban species such as lime and sycamores, and analysed to derive indicators of subsurface conditions. Each unit is then assigned a classification reflecting relative levels of intervention, resulting in a spatially distributed representation of management priorities. In this study, the focus is extended to the subsequent interpretation stage by explicitly defining and applying alternative strategies to aggregate zone-level classifications into tree-level representations. These include majority-based, worst-case, and proportional approaches, each providing a different synthesis of the same underlying geophysical evidence.

The results show that different aggregation strategies applied to identical zone-level classifications can lead to markedly different tree-level interpretations. This demonstrates that the transition from spatially resolved evidence to asset-level interpretation is not neutral, but depends on how the aggregation is performed. Formalising this step, the study enhances transparency and reproducibility in GPR-based assessment workflows and provides a structured basis for integrating subsurface information into practical evaluation workflows, supporting consistent interpretation and prioritisation in urban tree and infrastructure management.

sciforum-181897: Magnetometry and Gradiometry for Archaeological Prospection: Developments in Ground and UAV-Based Surveys.

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Applied geophysics provides a range of non-invasive techniques that allow researchers to detect buried structures and characterize the physical properties of materials in archaeological contexts. Among the different geophysical approaches, the magnetic method is widely used because it is efficient, relatively fast, cost-effective, and non-destructive. This technique exploits variations in magnetic susceptibility between archaeological features and the surrounding soil. Such contrasts generate small disturbances in the measured Earth's magnetic field, known as magnetic anomalies, which can be analysed to identify and map subsurface remains. However, anomalies produced by archaeological targets are usually weak, localized, and often overlap with one another. For this reason, the acquisition of high-resolution magnetic data is crucial.

One particularly effective application of the magnetic method in archaeology is the use of gradiometric surveys. In this configuration, the magnetic gradient is measured rather than the total magnetic field. This approach enhances the visibility of shallow sources and significantly improves data resolution. Gradiometric systems usually employ two sensors positioned at different heights, allowing the instrument to emphasize local anomalies while reducing the influence of regional magnetic fields and temporal variations. As a result, features related to archaeological remains can be identified more clearly.

In recent years, advances in applied geophysics have further improved data acquisition through the use of Unmanned Aerial Vehicles (UAVs) equipped with miniaturized magnetometers. UAV-based magnetic surveys enable the rapid investigation of large areas at low altitudes, producing high-resolution datasets. This technology is particularly valuable in environments where traditional ground surveys are difficult to perform.

We showcase the potential and latest advancements in the use of both ground- and UAV-based magnetometric sensors, also in vertical gradiometer configurations, for the discovery and diagnosis of archaeological remains.

sciforum-183387: Sub-molecular Structural Quality Assessment of Australian Faba Bean Using ATR-FTIR

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Faba bean (*Vicia faba* L.), also known as broad bean, has recently experienced renewed interest due to its potential as a functional food, in conjunction with its rising use in plant-based meat alternatives. Australia is the fourth largest producer of faba bean and is the largest exporter, being responsible for one-third of the international trade market. In this study, attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy was applied to ten commercial varieties of Australian faba bean, in order to profile the differences in the sub-molecular structural composition of the major nutritional constituents, namely proteins, starch, structural carbohydrates and lipids. Following identification of the major structural features present and their various secondary structures, quantification of the peak heights and areas allowed differences in the relative proportion of various structural carbohydrate and amide constituents to be observed between varieties. Key varietal differences were observed in the ratios of α-helices: β-sheet protein structures (range 0.945 – 0.956) and crystalline: amorphous starch structures (range 0.884 – 0.904). Given that the secondary structure of nutritive compounds influences their digestibility *in vivo*, these differences in secondary structure may contribute to the differential digestibility or nutritional value of seed material from these varieties. ATR-FTIR shows promise for the rapid assessment of such structural features in intact crops.

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