Program of the
Midnight Sun Summit in Mathematics and Engineering
Preliminary version, under construction

June 15–19, 2026

Contents

Presentation **1**
- Scientific Committee . . . 1
- Sponsors and Supporting Partners . . . 2

Program **3**

Special Activities **7**
- PhD Day . . . 7
- Welcome grill . . . 7
- City tour . . . 7
- Conference Dinner . . . 7

Abstracts **9**
- Plenary talks . . . 9
- Applied Artificial Intelligence and Machine Learning . . . 14
- Electrical Energy Systems: Mathematical Modeling, Simulation, and Case Studies . . . 17
- Geometry and Optimization . . . 20
- Industrial Applications and Mathematical Modeling . . . 25
- Mathematics and Mathematical Modelling: Fourier Analysis and Optimization . . . 29
- Mathematics and Mathematical Modelling: Homogenization . . . 30
- Mathematics and Mathematical Modelling: Mathematics . . . 31
- Mathematics and Mathematical Modelling: Modelling and Statistics . . . 35
- Mathematics and Mathematical Modelling: Scientific Computing . . . 37
- Structural Health Monitoring of Civil Engineering Structures and Infrastructures . . . 39
- Technologies for Sustainable Urbanization in the Arctic: Environmental Engineering . . . 44
- Technologies for Sustainable Urbanization in the Arctic: Fuel Cells . . . 47
- Technologies for Sustainable Urbanization in the Arctic: Materials and Modelling . . . 49
- Poster session . . . 52

Index **59**

Presentation

It is a pleasure to present the book of abstracts for the inaugural Midnight Sun Summit in Mathematics and Engineering. This document compiles the diverse academic contributions, vanguard research, and innovative expositions that define the current scientific landscape at the intersection of these two vital fields.

Since its conception, the summit was envisioned as a dynamic arena to highlight recent advances and address outstanding challenges where mathematics and engineering converge. Our hope is that this rich variety of high-quality submissions will help us foster an environment uniquely conducive to interdisciplinary exchange, networking, and the cross-pollination of ideas.

With such varied professional trajectories among our attendees, we hope this conference will serve as a vital platform for researchers at all career stages—from graduate students launching their careers to internationally recognized scholars sharing mature insights. Furthermore, we aspire to leverage the participation of several key industry partners to strengthen our objective of bridging the gap between theoretical research and practical application, ultimately deepening the ties between Scandinavia and the global research community.

We extend our deepest gratitude to all the authors, reviewers, and committee members whose dedication made this meetup possible. We are incredibly optimistic about this first edition and look forward to seeing the seeds planted here flourish in the years to come.

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Lars-Erik Persson
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Harpal Singh

UiT The Arctic University of Norway
Narvik, June 2026

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- The Lie–Størmer Center
- UiT The Arctic University of Norway

Program

Monday

08:00-09:00	Registration	
09:00-09:20	Opening	*Audit. 1*
09:20-10:10	**Hans Georg Feichtinger**	*Audit. 1*
10:10-10:30	Coffee break	
10:30-12:20	Parallel sessions	
	Fuel Cells: **Borissova**, **Azhar**, **Al-Hamdan**	*Audit. 1*
	Modelling & Statistics: **Konjik**, **Birdac (Fildan)**, **Enerbäck**	*Audit. 2*
	Industrial Applications: **Boiger**, **Gupta**	*Audit. 5*
	Structural Health Monitoring: **Storni**, **Spina**, **Patel**	*Audit. 4*
	PhD Day: Panels on peer review and on transition to industry.	*Audit. 3*
12:20-13:30	Lunch and poster set-up	
13:30-14:20	**Satoshi Okabe**	*Audit. 1*
14:20-14:40	Coffee break	
14:40-16:20	Parallel sessions	
	Environmental Engineering: **Dang**, **Thakur**, **Khader**	*Audit. 1*
	Geometry & Optimization: **Henriksen**, **Arjmand**, **Geleta**	*Audit. 3*
	Modelling & Statistics: **Kaslik**, **Nguyen**	*Audit. 2*
	Industrial Applications: **Patil**, **Vaseem**	*Audit. 5*
	Structural Health Monitoring: **Petrich**, **Berg**, **Schlanbusch**	*Audit. 4*
16:20-16:30	Break	
16:30-17:20	**Wil Schilders**	*Audit. 1*
17:30-20:00	Welcome grill	

Tuesday

08:00-09:10	Registration	
09:10-10:00	**Jean-Bernard Lasserre**	*Audit. 1*
10:00-10:20	Coffee break	
10:20-12:10	Parallel sessions	
	Electrical Energy Systems: **Huynh**, **Redoy**, **Tedla**	*Audit. 5*
	General Mathematics: **Sawano**, **Yeshitla**, **Bocci**	*Audit. 2*
	Homogenization: **Braides**, **Piatnitski**	*Audit. 3*
	Industrial Applications: **Mustafa**, **Kumar**	*Audit. 1*
	Structural Health Monitoring: **Quarchioni**, **Bayazid**, **Nwamma**	*Audit. 4*
12:10-13:30	Lunch	
13:30-14:20	**Suresh Bhalla**	*Audit. 1*
14:20-14:40	Coffee break	
14:40-16:20	Parallel sessions	
	Electrical Energy Systems: **Nazari**, **Palavai**, **Pichika**	*Audit. 5*
	Geometry & Optimization: **Lakså**, **Jankowsky**, **von Bargen**	*Audit. 2*
	Homogenization: **Panasenko**, **Nedic**	*Audit. 3*
	Industrial Applications: **Nabi**, **Upreti**	*Audit. 1*
	Structural Health Monitoring: **Bjerknes**, **Mohammadreza**	*Audit. 4*
16:20-16:30	Break	
16:30-17:20	**Bjorn Birnir**	*Audit. 1*

Wednesday

08:00-09:00	Registration	
09:10-10:00	**Gianni Dal Maso**	*Audit. 1*
10:00-10:20	Coffee break	
10:20-12:10	Parallel sessions	
	Applied AI & ML: **Malmberg**, **Fahimi**, **Srivastava**	*Audit. 4*
	Environmental Engineering: **Ejigu**, **Asokan**, **Mishra**	*Audit. 1*
	General Mathematics: **Samko**, **Jain**	*Audit. 2*
	Scientific Computing: **Uddin**, **Nylund**, **Rodriguez Velasco**	*Audit. 3*
12:10-12:15	Conference photo	
12:15-13:00	Lunch	
13:00-14:30	Poster session: **Aidoo**, **Al-Hadeethi**, **Azhar**, **Bhandari**, **Derso**, **Finke**, **Lakdawala**, **Łukasik**, **Otsiwah**, **Scholtz**, **Sinha**, **Taief**, **Todorokihara**, **Tomljanović**	
14:30-18:00	City tour	
19:00-21:00	Conference dinner	

Thursday

08:00-09:10	Registration	
09:10-10:00	**Barbara Kaltenbacher**	*Audit. 1*
10:00-10:20	Coffee break	
10:20-12:10	Parallel sessions	
	Applied AI & ML: **Tangrand**, **Patil**, **Wally**	*Audit. 4*
	Fourier Analysis: **Tephnadze**, **Tutberidze**, **Evgrafov**	*Audit. 2*
	Geometry & Optimization: **Munthe-Kaas**, **Kosmač**, **Corona Sanchez**	*Audit. 3*
	Urbanization Materials: **Madaan**, **Yashwant**, **Kapoor**	
12:10-13:30	Lunch	
13:30-14:20	**Rune Brincker**	*Audit. 1*
14:20-14:40	Coffee break	
14:40-16:10	Parallel sessions	
	Applied AI & ML: **Srivastava**, **Wally**	*Audit. 4*
	General Mathematics: **Yagoubi**, **Asfaw**, **Asif**	*Audit. 2*
	Geometry & Optimization: **Rouillier**, **Vitrih**	*Audit. 3*
	Urbanization Materials: **Entner**, **Malila**	*Audit. 1*
16:20-16:30	Break	
16:30-17:20	**Luboš Pick**	*Audit. 1*

Friday

08:00-09:10	Registration	
09:10-10:00	**Adrian Muntean**	*Audit. 1*
10:00-10:20	Coffee break	
10:20-12:10	Parallel sessions	
	General Mathematics: **Turčinová**, **Ågotnes**, **Londoño Orozco**	*Audit. 2*
	Geometry & Optimization: **Ratsaby**, **Mascarin**	*Audit. 3*
	Urbanization Materials: **Das**, **Thanh**, **Taj**	*Audit. 1*
12:10-12:30	Lunch (sandwich)	
12:30-13:20	**Arash Soleiman Fallah**	*Audit. 1*
13:20-13:30	Closing	

Special Activities

PhD Day

On Monday, we will hold the following program of PhD Day activities in parallel with the other sessions of the conference:

10:30-11:20	**Introduction to the Peer Review Process and Editorial Workflows** A comprehensive guide to the backend of standard academic hosting platforms (such as EasyChair). This session pulls back the curtain on how editors select referees, what a reviewer looks for during an evaluation, and how to interpret conflicting referee reports.
11:20-12:20	**Academic-to-Industry Skill Translation and Transition** Learn how to successfully transition from academia to industry. This session focuses on how to deconstruct abstract research (e.g., advanced optimization, numerical analysis, or fluid dynamics) and translate your technical expertise into high-impact skills that align directly with industry requirements.

The conference will also hold networking opportunities during the Welcome grill, the Poster session, the City tour, and the the Conference dinner. → *Full program*

Welcome Grill

Monday 17:30-20:00 at the Kantina

Join us at the canteen and —weather permitting— the outside area to enjoy some delicious grilled fish, meat, and vegetables! The student bar will also be open if you would like to accompany that with a beverage. The event is free for everyone in the conference; only alcoholic drinks will need to be purchased separately. → *Full program*

City Tour

Wednesday 14:30-18:00, leaving from the university

We will go together to explore Narvik city's most important sights, including a visit to the War Museum. We will make a stop to have a beer and enjoy the afternoon together. → *Full program*

Conference Dinner

Wednesday 19:00-21:00 at the Linken Restaurant & Bar (located in the Quality Hotel Grand Royale)

A premium three-course dinner featuring the finest local Norwegian cuisine. This evening offers a fantastic opportunity to connect with fellow participants, share insights, and expand your professional network in a relaxed setting.

The deadline to register for the conference dinner is Monday, June 15. → *Full program*

Abstracts

Plenary talks

Mathematics to Market: The Indian Journey in Structural Health Monitoring Technologies and Start-ups

Suresh Bhalla, Indian Institute of Technology Delhi

Abstract. Mathematics forms the backbone of modern engineering, providing the language and analytical framework through which complex physical phenomena are understood, modeled, and controlled. The field of Structural Health Monitoring (SHM), which emerged in academic circles during the early 1990s as a logical progression beyond the limitations and stagnation of conventional Non-Destructive Evaluation (NDE) techniques, is no exception. Over the past three decades, SHM has evolved into a truly multidisciplinary scientific domain integrating concepts from civil, mechanical, aerospace, and electrical engineering, along with applied mathematics, signal processing, data analytics, artificial intelligence, and machine learning. At its core, SHM seeks to make engineering structures "self-aware" by enabling them to sense, interpret, and communicate signs of distress, deterioration, or abnormal behavior in real time. Such capabilities are increasingly vital for ensuring the safety, resilience, and longevity of critical infrastructure systems including bridges, buildings, pipelines, industrial plants, and transportation networks. This paper presents how more than two decades of academic research at the Smart Structures and Dynamics Laboratory, IIT Delhi, has progressively translated into tangible technologies, engineering products, industrial solutions, and fully operational start-ups. What initially began as curiosity-driven fundamental research in sensing technologies, vibration-based diagnostics, smart materials, and structural dynamics has gradually evolved into India-centric SHM solutions addressing practical challenges faced by infrastructure systems in developing economies. The talk will highlight the journey from laboratory-scale concepts to field-deployable technologies, emphasizing the importance of indigenous innovation, affordability, scalability, and adaptability to local infrastructure conditions. Particular attention will be given to the challenges confronting SHM in developing countries, including economic constraints, lack of large-scale sensing infrastructure, maintenance limitations, environmental variability, and the gap between academic research and field implementation. The presentation will further discuss possible strategies for accelerating SHM adoption in resource-constrained environments through minimalistic and incremental deployment approaches, low-cost sensing ecosystems, data-driven intelligence, and Made-in-India technological development. The broader objective is to demonstrate how scientifically rigorous yet economically viable SHM technologies can contribute toward safer, smarter, and more sustainable infrastructure systems for the future. *→ Full program*

The Stochastic Closure Theory of Turbulence

Björn Birnir, University of California, Santa Barbara

Abstract. We present a statistical theory of turbulence, as postulated by Kolmogorov and Obukhov in 1962, based on stochastic closure. This problem closes the RANS equations proposed by Reynolds, for the large-scale motion, by adding a stochastic Navier-Stokes equation for the small scales. The noise is shown to be generic. The moments of the velocity are skewed Gaussians, but the structure functions have a scaling as proposed by Kolmogorov and Obukhov, with intermittency corrections given by She-Leveque-Frisch-Parisi log-Poisson processes. These processes are derived from multiplicative jumps in the stochastic Navier-Stokes equation. We prove ergodicity for the stochastic Navier-Stokes equations and obtain an equation with strong solutions that are Markov processes. This equation is shown to have

a unique invariant measure that can be computed explicitly. Then the structure functions are computed and the probability density function for the velocity differences. The theory is applied to derive the statistical theory of homogeneous turbulence, boundary and Lagrangian turbulence. → *Full program*

Time to act in the field of Structural Health Monitoring (SHM)

Rune Brincker, Brincker Monitoring

Abstract. SHM has been known as a concept over quite a long time back from the sixties and seventies. However, we still do not use data a lot in order to prevent the two big mistakes from knowing nothing i) the sudden failure known from the Genova bridge and the Alexander Kielland platform, or ii) tearing down structures because we are not sure that they are safe. The technologies are there, but not being used as one could expect. We will point to how measurements and response data can add to our knowledge, how mathematical methods like operational modal analysis (OMA) have been developed to extract information from the random responses, and also give introduction to more simpler ways of analyzing data like using Principal Component Analysis. → *Full program*

Gamma-Convergence and stochastic homogenization for functionals in the A-free setting

Gianni Dal Maso, SISSA, Italy

Abstract. We obtain a compactness result for Gamma-convergence of integral functionals defined on A-free vector fields. This is used to study homogenization problems for these functionals without periodicity assumptions. More precisely, we prove that the homogenized integrand can be obtained by taking limits of minimum values of suitable minimization problems on large cubes, when the side length of these cubes tends to infinity, assuming that these limit values do not depend on the center of the cube.
→ *Full program*

Engineering the Unnatural: How Metamaterials Will Shape Future Technologies

Arash Soleiman Fallah, OsloMet

Abstract. For centuries, engineering has relied primarily on the use of naturally available materials whose mechanical and physical properties are fundamentally constrained by chemistry and composition. Metamaterials challenge this paradigm by enabling the creation of latticed engineered systems whose behaviour emerges predominantly from the geometry, architecture, and topology of the unit cell rather than the constituent materials alone. Through carefully designed micro- and meso-scale structures, metamaterials can exhibit extraordinary and often counterintuitive properties that do not exist in conventional materials, including negative Poisson's ratio, programmable stiffness, adaptive wave manipulation, multistability, negative effective mass and stiffness, and tunable bandgaps, among others. These capabilities are redefining the limits of what engineered systems can achieve.

This keynote will present recent advances in the modelling, analysis, and design of phononic, auxetic, and multistable metamaterials, with emphasis on the underlying mechanics governing their unusual behaviour and their potential for real-world engineering applications, while the mechanics governing their unconventional behaviour and their transformative potential across future technologies is an interesting topic in its own right. The presentation will discuss how phononic metamaterials can manipulate stress waves, vibrations, and acoustic energy through engineered dispersion and bandgap phenomena; how auxetic architectures achieve enhanced energy absorption, indentation resistance, and adaptive deformation through negative Poisson's ratio mechanisms; and how multistable systems enable programmable responses, shape reconfiguration, and energy-efficient adaptive structures. Attention will also be given to the role of instability, nonlinear mechanics, topology optimisation, and multiphysics interactions in enabling functionalities that are impossible to achieve using traditional engineering materials.

The keynote will further highlight how advances in computational mechanics, additive manufacturing, AI-assisted design, and multiscale modelling are accelerating the transition of metamaterials from theoretical concepts to deployable engineering systems. The applications span aerospace, vibration isolation, impact and blast mitigation, robotics, soft actuators, biomedical devices, energy systems, and adaptive infrastructure. Finally, the lecture will address the scientific and technological challenges that

remain, including scalability, manufacturability, robustness under extreme loading, multifunctionality, and integration with intelligent control systems. The emerging vision is one in which metamaterials fundamentally alter the relationship between structure and function, enabling engineers not merely to select materials, but to design entirely new physical behaviours on demand. *→ Full program*

Modern Mathematical Tools for Fourier Analysis illustrated by Applications in Physics and Engineering

Hans Georg Feichtinger, Universität Wien and ARI (OEAW)

Abstract. Fourier analysis has evolved far beyond its classical formulation in terms of Fourier series and integral transforms. During the last decades a broad variety of modern mathematical tools has emerged, allowing a refined analysis of signals, operators, and dynamical systems in both local and global settings. These developments have created strong new links between pure mathematics, physics, and engineering.

The lecture presents an overview of several contemporary approaches to Fourier analysis, with particular emphasis on time-frequency methods, Gabor analysis, wavelet theory, modulation spaces, and phase-space representations. These methods provide mathematically rigorous and computationally efficient frameworks for the analysis of nonstationary phenomena and localized structures.

From the viewpoint of mathematics, the talk discusses the role of functional analysis, Banach spaces, distribution theory, frame theory, and operator methods in the development of modern harmonic analysis. Concepts such as redundancy, stability, and localization play a central role and lead naturally to flexible signal representations adapted to practical applications.

The presentation also highlights the relevance of these ideas in physics and engineering. Examples arise in quantum mechanics, optics, acoustics, wireless communication, imaging sciences, and signal processing. Special attention will be given to the use of phase-space methods and localized Fourier techniques for the study of wave propagation, filtering, sampling, and numerical approximation.

The overall goal of the lecture is to demonstrate how abstract mathematical concepts can lead to efficient analytical and computational tools, and how engineering challenges in turn stimulate the development of new mathematical theories. Fourier analysis thus appears not only as a classical discipline, but as a continuously evolving framework connecting mathematics with modern scientific and technological applications. *→ Full program*

Forward and Inverse Problems in Nonlinear Acoustics

Barbara Kaltenbacher, Alpen-Adria-Universität Klagenfurt

Abstract. The importance of ultrasound is well established in the imaging of human tissue. In order to enhance image quality by exploiting nonlinear effects, recently techniques such as harmonic imaging and nonlinearity parameter tomography have been put forward. As soon as the pressure amplitude exceeds a certain bound, the classical linear wave equation loses its validity and more general nonlinear versions have to be used. Another characteristic property of ultrasound propagating in human tissue is frequency power law attenuation leading to fractional derivative damping models in time domain.

This talk we will first of all provide some background on modeling of nonlinearity on one hand and of fractional damping on the other hand, also giving an idea on the challenges in the analysis of the resulting PDEs. In the practically relevant case of periodic excitations with a source operating at a single or a few frequencies, it is useful to formulate the problem in frequency domain by means of a multiharmonic expansion. In order to justify this, existence of periodic solutions needs to be proven and we will report on recent joint work with Teresa Rauscher (University of Klagenfurt) and Benjamin Rainer (Austrian Institute of Technology) on this.

In the second part of the talk, we address some relevant inverse problems in this context, in particular the above mentioned task of nonlinearity parameter imaging, which leads to a coefficient identification problem for a quasilinear wave equation. In particular, we investigate the recovery of the nonlinearity coefficient commonly labeled as B/A in the literature, which is part of a space dependent coefficient κ in the Westervelt equation governing nonlinear acoustics. Corresponding to the typical measurement setup, the overposed data consists of time trace measurements on some manifold Σ representing the receiving transducer array. We will show some recent results pertaining to the formulation of this inverse problem in frequency domain and numerical reconstruction of piecewise constant coefficients in two space dimensions. The latter is joint work with Bill Rundell (Texas A&M University). *→ Full program*

The Christoffel function: some applications

Jean-Bernard Lasserre, LAAS-CNRS and Toulouse School of Economics

Abstract. Even though the Christoffel function (CF) is well-known in approximation theory and orthogonal polynomials, it is only recently that some of its remarkable properties have been shown to be useful in some other applications, like data analysis and mining (e.g. for outlier detection and support inference), and approximation of possibly discontinuous functions with no Gibbs phenomenon. So in this talk we will briefly introduce the CF and describe how some of its main features can be exploited in some applications. Moreover we will also describe connections of the CF with seemingly unrelated fields, like positive polynomials, Pell's equation and equilibrium measure of compact sets, and if time permits, we will introduce some variants with interesting additional properties. *→ Full program*

Organic solar cells and mathematics of phase separation for interacting ternary mixtures under evaporation: The unexpected story of a non-local evolution system

Adrian Muntean, Karlstad University, Sweden

Abstract. Broadly seen, the research reported in this talk is motivated by our interest in using well-established mathematical methodologies to understand materials science aspects that we believe are responsible for the steadily increasing efficiency of organic solar cells (OSC) when harvesting solar energy [7]. In particular, as morphologies play a key role in the well-functioning of OSCs, we focus now only on their formation although our scientific curiosity has a deeper goal - unveiling the morphology's ability to transport efficiently charges. From a more concrete point of view, being very much inspired by experimental evidence collected when processing thin films from ternary solutions made of two solutes, typically polymers, and one solvent, we study computationally the morphology formation of domains obtained in three-state systems using both a lattice (microscopic) model and a continuum (macroscopic) counterpart. The lattice-based approach relies on the Blume-Capel nearest neighbor model with bulk conservative Kawasaki dynamics (see [4]), whereas as continuum model we consider a coupled system of evolution equations (with nonlinear nonlocal drifts) that is derived as hydrodynamic limit when replacing the nearest neighbor interaction in the lattice case by a suitable Kac potential (see [1]). We explore numerically (in both 2D and 3D) how the obtained morphology depends on the solvent content in the mixture. In particular, we study how these scenarios change when the solvent is allowed to evaporate [5]. Essentially, we illustrate how the evaporation process affects the shape and connectivity of the evolving-in-time morphologies. Finally, we give a statement about the well-posedness of the continuum model, sketch the proof of our result (see [3] for the details), and then point out how well our finite volumes schemes are able to construct approximations of the wanted weak solution [5]. The technical details on how our numerical scheme dissipates an approximate energy of the system can be retrieved from [2]. This is a report on recent joint work with Nicklas Jävergård (Karlstad University, Sweden), Rainey Lyons (University of Colorado Boulder, USA), Stela Andrea Muntean (Karlstad University, Sweden), and Emilio N.M. Cirillo (La Sapienza University, Rome, Italy). We acknowledge funding from the Swedish Research Council via the project "*Homogenization of Nonlinear Drift-diffusion Systems for Charge Transport through Bicontinuous Media*" (nr. 2024-05606).

[1] Lyons, R., Muntean, S. A., Cirillo, E, N. M., Muntean, A. *A continuum model for morphology formation from interacting ternary mixtures: Simulation study of the formation and growth of patterns*, Physica D: Nonlinear Phenomena, Vol. 453 (2023), 133832.

[2] Lyons, R., Muntean, A., Nika, G., *A bound preserving energy stable scheme for a nonlocal Cahn–Hilliard equation*, Comptes Rendus Mécanique, Vol. 352 (2024), pp. 239-250.

[3] Lyons, R., Cirillo, E, N. M., Muntean, A., *Phase separation and morphology formation in interacting ternary mixtures under evaporation: Well-posedness and numerical simulation of a non-local evolution system*, Nonlinear Analysis: Real World Applications, Vol. 77 (2024), 104039.

[4] Cirillo, E, N. M., Colangeli, M., Moons, E., Muntean, A., Muntean, S. A., van Stam, J., *A lattice model approach to the morphology formation from ternary mixtures during the evaporation of one component*, The European Physical Journal Special Topics, Vol. 228 (2019), 5, 55-68.

[5] Jävergård, N., Lyons, R., Muntean, A. *Semi-discrete finite volume approximations of coupled evolution equations for ternary mixtures: convergence and 3D morphological studies*, Discrete and Continuous Dynamics Systems (DCDS), Series S, (2025).

[6] Cirillo E. N. M., Jävergård, N., Lyons, R., Muntean, A., S. A. Muntean *3D morphology formation in a mixture of three differently averse components*, Modelling and Simulation in Materials Science and Engi-

neering, Vol. 33, 055014, (2025).

[7] Zhang, R., Chen, H., Wang, T. et al., *Equally high efficiencies of organic solar cells processed from different solvents reveal key factors for morphology control*. Nature Energy (2024). *→ Full program*

TBA

Satoshi Okabe, Hokkaido University

Abstract. TBA *→ Full program*

Nonimprovability of sharp endpoint estimates

Luboš Pick, Charles University

Abstract. Our point of departure will be the question whether boundedness properties of an operator whose endpoint estimates are known can be substantially improved in terms of function spaces beyond one of the endpoints. We shall focus on important operators acting in harmonic analysis and mathematical physics such as the Riesz potential. We shall describe two new techniques each of which can be used to give a negative answer to the question in a fairly general situation. This is a joint work with Zdeněk Mihula (Czech Technical University, Prague) and Armin Schikorra (University of Pittsburgh).
→ Full program

Towards a New Mathematical Foundation for Scientific Machine Learning: Bridging Mathematics, Engineering, and Industrial Innovation

W.H.A. (Wil) Schilders, Eindhoven University of Technology and Hans Fischer Senior Fellow, TU Munich-IAS

Abstract. The increasing complexity of modern engineering systems is driving an urgent need for faster, more reliable, and more adaptive computational models. Across many industrial domains, including advanced manufacturing, materials science, energy systems, and digital twins, high-fidelity simulations have become indispensable, yet their computational cost often prevents their use in real-time decision making, optimization, and large-scale design exploration.

At the same time, recent advances in artificial intelligence and machine learning are potentially creating new opportunities for accelerating scientific computation. However, these approaches frequently struggle with reliability, interpretability, physical consistency, and extrapolation beyond the training regime. This has led to the emergence of Scientific Machine Learning (SciML), a rapidly developing field at the interface of mathematics, scientific computing, engineering, and artificial intelligence.

In this lecture, we discuss how modern numerical mathematics can provide the foundations for the next generation of scientific machine learning methods. We present recent developments in hybrid approaches that combine physics-based modelling with data-driven learning, including reduced-order modelling, operator learning, structure-preserving methods, and physics-informed architectures. Particular emphasis will be placed on the role of mathematical structure in ensuring robustness, efficiency, and physical reliability.

We further discuss how ideas originating from scientific computing, such as localization, multiscale methods, model reduction, and structure preservation, are increasingly influencing the design of modern artificial neural networks and learning algorithms. These developments point towards a new generation of mathematically grounded AI methods that are better suited for complex engineering applications.

The central message of the talk is that the future of AI for science and engineering will not be driven by machine learning alone, but by a deep integration of mathematics, physical insight, and computational science. Building these bridges between disciplines is essential for transforming recent AI advances into reliable industrial technologies and scientific breakthroughs. *→ Full program*

Session on Applied Artificial Intelligence and Machine Learning

Session chairs: Kalyan Ram Ayyalasomayajula and Elisabeth Wetzer

→ Full program

Session program

Wednesday	10:20-11:10	**Malmberg**
	11:10-11:40	**Fahimi**
	11:40-12:10	**Srivastava**
Thursday	10:20-10:50	**Tangrand**
	11:00-11:30	**Patil**
	11:40-12:10	**Wally**

Porting deep ML/AI models to edge devices without retraining

Kalyan Ram Ayyalasomayajula, UiT The Arctic University of Norway

Abstract. Deep learning models are currently widely used for their superior performance and ability to be trained end-to-end over down stream tasks. It is common to import weights from standard models and fine-tune them for the task at hand to achieve desired results. With the advent of wearable devices and ubiquitous mobile device porting these models to such device is gaining traction to encourage real-time user interaction using these models. However, it is common to see such model deteriorate in performance when ported to edge/network devices. In this talk we show our findings to retain performance of these models on edge devices without the need to retrain.

→ Session program

Machine learning-based crystal plassticity model for form limit predictions of sheet metal

Pouya Fahimi, UiT The Arctic University of Norway - Narvik

Abstract. Forming limit diagram (FLD) is a valuable tool in designing sheet metal forming operations. The diagram may be obtained experimentally, but the procedure is complex and costly. A number of works used plasticity models to predict the FLD based on a limited set of tests. Crystal plasticity (CP) has been used to predict FLD based on the crystallographic texture data and stress-strain curve of the metal. The study proposes use of a novel data-driven CP model for constructing the FLD of an Al alloy. The results are compared to conventional phenomenological CP model and experimental data available in the literature.

→ Session program

Revisiting greedy algorithms for solving hard optimization problems

Filip Malmberg, Uppsala University

Abstract. Many problems in applied data- and computer science are naturally formulated as optimization problems. In this paradigm, we solve problems by first formulating a criterion that describes the qualities of a good solution. We then use various optimization methods to find a solution that is as good as possible according to our chosen criterion. The ubiquity of this approach to problem solving means that good optimization methods are a key enabling technology in many areas of computer science and its many applications.

In this talk, we study a certain class of greedy algorithms for combinatorial optimization. Several interesting optimization methods published in recent years follow a similar "greedy" algorithmic pattern, yet their properties and optimality have generally been studied for each method in isolation. We formulate a generalized version of this algorithmic pattern, and study the properties of the solutions computed with this approach. To characterize the optimality of such solutions, we study them through the lens of so-called lexicographic max-ordering (Lex-MO) multicriteria optimization. Our key insight is that under certain conditions, the problem of finding a Lex-MO optimal solution to a multi-criteria optimization problem can be transformed into a sequence of constraint satisfaction problems. If we can solve the associated constraint satisfaction problems, we can find a Lex-MO optimal solution. By presenting a unified formulation of this class of greedy algorithms, we hope to facilitate the development of

new such algorithms, and to provide a deeper understanding on the properties of existing algorithms.
→ *Session program*

A MultiSensor Imaging Framework for AI-Driven Raspberry Crop Monitoring: Design, Field Protocols, and Early Progress

Ravindra R Patil, HVL, Norway

Abstract. Raspberry production is increasingly challenged by climate variability, emerging diseases, and pressure to reduce chemical inputs while maintaining yield and quality. This paper presents a multisensor imaging framework that lays the foundation for AI-driven raspberry crop monitoring, with a focus on system design, data collection protocols, and early progress within the FutuRaPS project. The framework integrates hyperspectral, multispectral, and RGB imaging into a coordinated acquisition and processing pipeline, targeting canopy and plot level monitoring across cultivars and management treatments. We describe the overall system architecture, including sensor configuration, geometric and radiometric calibration, and spatial alignment between modalities. Standardized field protocols are outlined for repeated measurements over time, ensuring temporal consistency and enabling comparison between datasets, treatments, and season. The Season 2025 campaign is summarized with emphasis on experimental layout, sampling strategy, and the structure of the resulting multisensor datasets. Early results include operational workflows for reflectance conversion, vegetation index computation, spectral feature extraction, and generation of basic map products for vigor and stress visualization. Overall, the proposed framework and datasets establish a robust platform for subsequent development of machine learning and deep learning methods for disease detection, vigor assessment, and yield and fruit quality trait prediction (e.g., soluble solids content) in raspberry production systems. → *Session program*

Beyond Policy Learning: Reinforcement Learning for Environment–Policy Co-Design

Amber Srivastava, Indian Institute of Technology Delhi

Abstract. In this talk, I will present our ongoing work on Reinforcement Learning (RL) for environment–policy co-design. More precisely, I will discuss a framework that extends the class of problems traditionally addressed by RL. In standard RL settings, an agent learns an optimal policy through repeated interactions with an environment. By observing the environment's response to its actions, the agent updates its policy—often without explicitly learning the underlying system dynamics (model-free RL). Once training is complete, the learned policy recommends an action based on the current state of the system so as to maximize the long-run cumulative reward of the underlying Markov Decision Process (MDP). In contrast, this talk focuses on a class of problems—commonly referred to as co-design problems in control theory—where the objective is to determine unknown parameters of the environment along with the agent's policy. These unknown parameters could potentially be governing the underlying dynamics, or structural properties of the environment. In other words, the goal is to simultaneously design the environment and the RL policy so that the expected cumulative reward of the underlying MDP is maximized. As a motivating example, consider a shortest-path problem on a graph where the spatial locations of some vertices are not yet fixed. The objective is to jointly determine the locations of these vertices (environment parameters) and the optimal routing policy from each vertex to a designated terminal node. In this talk, I will discuss current approaches to addressing such co-design problems in the model-free RL setting, and highlight potential improvements and generalizations, with applications in manufacturing systems, supply chain and logistics, and communication networks. Note: Parts of this work are currently under review. → *Session program*

Conversational Spatial Intelligence for Railway Operations: An LLM Interface for Railway Data Spaces

Kristoffer Tangrand, NORCE

Abstract. When disruption occurs on a rail network, operators often have to piece together information from several separate information sources, such as infrastructure monitoring, traffic management, and weather data. This can mean monitoring multiple dashboards, navigating the right datasets, and setting up each step of the analysis by hand, which takes time in situations where time matters. We present a conversational interface for a railway data space that lets operators ask questions in natural language

instead of starting with tools or datasets. The framework uses a large language model to identify and query relevant data sources and generate spatial outputs such as maps, dashboards, and overlays. This helps operators investigate issues without needing to know in advance what data exists or how it is organized. The paper describes the system architecture and data integration approach, and argues that conversational access to railway data can improve situational awareness and support faster operational decisions. → *Session program*

Hyperbolic Representation Learning for Spatial Biology: Evaluating Cell Type Hierarchies in Breast Cancer Imaging Data

Youssef Wally, UiT The Arctic University of Norway

Abstract. Hyperbolic representation learning has shown compelling advantages over conventional Euclidean representation learning in modelling hierarchical relationships in data. In this work, we evaluate its potential to capture biological relations between cell types in highly multiplexed imaging data, where capturing subtle, hierarchical relationships between cell types is crucial to understand tissue composition and functionality. Using a recent and thoroughly validated 42-marker Imaging Mass Cytometry (IMC) dataset of breast cancer tissue, we embed cells into both Euclidean and Lorentzian latent spaces via a fully hyperbolic variational autoencoder. We then introduce an information-theoretic framework based on k-nearest neighbour estimators to rigorously quantify the clustering performance in each geometry using mutual information and conditional mutual information. Our results reveal that hyperbolic embeddings retain significantly more biologically relevant information than their Euclidean counterparts. We further provide open-source tools to extend Kraskov-Stögbauer-Grassberger based mutual information estimation to Lorentzian geodesic spaces, and to enable UMAP visualizations with hyperbolic distance metrics. This work contributes a principled evaluation method for geometry-aware learning and supports the growing evidence of hyperbolic geometry's benefits in spatial biology. Code is available at: https://github.com/youssefwally/FlatlandandBeyond → *Session program*

Session on Electrical Energy Systems: Mathematical Modeling, Simulation, and Case Studies

Session chair: Pawan Sharma → *Full program*

Session program

Tuesday	10:20-11:10	**Huynh**
	11:10-11:40	**Redoy**
	11:40-12:10	**Tedla**
	14:40-15:10	**Nazari**
	15:10-15:40	**Palavai**
	15:40-16:10	**Pichika**

Integrated Modeling, Simulation, and AI for Next-Generation Electric Powertrains in the Energy Transition

van Khang Huynh, University of Agder

Abstract. TBA → *Session program*

PMU Placement in Transmission Networks for Optimizing Observability and Wide Area Control Implementation

Afshin Nazari, UiT the Arctic University of Norway

Abstract. This study investigates power system observability and controllability through two complementary stages, namely optimal PMU placement and wide-area control enhancement. In the first stage, system observability is addressed by determining the optimal locations of Phasor Measurement Units (PMUs) in transmission grids using the Connectivity Matrix Algorithm (CMA). The analysis is carried out both without and with consideration of Zero Injection Buses (ZIBs), since ZIBs can improve network observability and reduce the number of PMUs required. The proposed method is validated in MATLAB R2024a on the IEEE-9, IEEE-14, and IEEE-24 bus test systems. The obtained results confirm that the CMA provides an effective and computationally efficient approach to achieve full observability, while the inclusion of ZIBs further reduces the required number of PMUs in some cases. In the second stage, the study focuses on controllability and system dynamic performance under renewable energy integration. For this purpose, a modified IEEE-9 bus system is considered under a Renewable Energy Source (RES)-based scenario, where the dynamic behaviour of the system is first examined without a controller. Pole-zero analysis reveals the presence of unstable oscillatory modes, highlighting the need for an effective control strategy. To address this issue, a controller based on the Deep Deterministic Policy Gradient (DDPG) algorithm is introduced within a Reinforcement Learning (RL) framework. The controller uses frequency signals acquired from PMUs through a Wide-Area Measurement System (WAMS), enabling it to react to global system conditions rather than relying merely on local measurements. The results show that the proposed RL-based Wide Area Control (WAC) strategy improves controllability of energy systems and enhances damping of low-frequency oscillations. Time-domain analysis demonstrates that the controller helps the disturbed system frequency return toward its nominal value, thereby contributing to improved dynamic stability. Overall, this study combines optimal PMU placement and advanced control design in a unified framework, showing that improved observability can support more effective WAC in transmission power networks with renewable energy integration. A useful basis is provided for future work on larger networks, more advanced RL algorithms, and practical implementation of PMU-supported wide-area control schemes. → *Session program*

Laser Induced Graphene assisted hematite Composite for Rapid Charge Supercapacitor Applications

Sowmya Sree Palavai, Birla Institute of Technology & Science Pilani, Hyderabad Campus

Abstract. Laser-induced graphene (LIG) is a relatively recent discovery that has emerged within the past decade. However, its properties have proven highly promising across a wide range of applications, including flexible energy storage systems, compact energy-harvesting devices, and electronic components such as field-effect transistors (FETs) and memristors. In this work, LIG was initially fabricated using a 30 W CO2 laser and evaluated as an electrode material for electrochemical energy storage systems. The laser process enables rapid thermal conversion of carbon rich substrates into a highly porous graphene-like network, enhancing ion accessibility and charge transport. To further enhance performance, LIG was subsequently modified with transition metal oxide (TMO) using a simple fabrication approach to obtain Ferrous-modified LIG (FL). Structural characterisation confirmed the successful formation of the porous graphene architecture and the uniform incorporation of hematite. The optimized FL electrodes exhibited electrochemical performance of 60 Wh Kg-1 with a power density of 3042 W Kg-1 at 5 Ag-1, thereby establishing FL as a highly promising electrode material for rapid energy-storage and high power supercapacitor applications. → *Session program*

Mathematical and Data-Driven Modelling of Degradation Behaviour of Hybrid Manufactured Laser-Patterned Supercapacitor Electrodes

S V V Srihari Pichika, Birla Institute of Technology and Science Pilani, Hyderabad Campus

Abstract. Accurate prediction of remaining useful life (RUL) is critical for reliable supercapacitor deployment, yet remains challenging due to degradation dependence on electrode design and operating conditions. This study investigates a data-guided approach for RUL estimation in laser-patterned supercapacitor electrodes fabricated on additively manufactured polymer substrates. Porous carbon electrodes were produced via CO_2 laser patterning, forming conductive networks with controlled microstructure. Raman spectroscopy revealed disordered graphitic features with ID/IG $\approx$ 0.95–1.0, while X-ray diffraction showed broadened (002) reflections indicating turbostratic carbon. The electrodes exhibited sheet resistances of 10^1–10^2 Ω/sq and stable electrochemical behaviour. Symmetric coin-cell supercapacitors were evaluated under constant-current and variable-current cycling, generating datasets up to 30,000 charge–discharge cycles. Initial areal capacitance ranged from 60 to 140 mF cm^{-2}. Constant-current cycling retained 65–70% capacitance after 30,000 cycles, whereas variable-current cycling reduced retention below 20% within 20,000 cycles. Regression-based models trained on 1,000 cycles accurately predicted lifetime with a mean absolute error of less than 5%. → *Session program*

Low-Cost Terracotta Separators and Carbon Black-Modified Anodes for Enhanced Stability in Bioelectrochemical Systems.

Md Daudul Islam Bhuiyan Redoy, UiT The Arctic University of Norway

Abstract. Bioelectrochemical systems (BES) face two main challenges that limit their wider use: the high cost and instability of polymer membranes (e.g., Nafion) and the limited performance of standard electrodes. This study has two main goals to address these problems: 1) to test unglazed terracotta ceramic as a robust, low-cost alternative to Nafion separators, and 2) to compare the performance of a carbon black (CB)-modified carbon paper anode (10% wt.) against standard materials (stainless steel mesh and standard carbon paper). Over 3 experiments, the study used both synthetic dairy wastewater (COD: 5302 mg/L) and high-strength real fish farm wastewater (COD: 8200 mg/L). The terracotta separator worked effectively, allowing stable ion movement and keeping pH levels balanced (6.3 to 7.7) in all tests. For the electrodes, the CB-modified anode showed much better stability, avoiding the sudden voltage drops and instability seen in standard electrodes when fuel is low. It reached a peak voltage of 310 mV in synthetic wastewater. In high-strength fish farm wastewater, it produced 51.3% higher peak voltage (160.81 mV vs. 106.29 mV) and kept its voltage much better (95.0% vs. 83.8%) compared to the stainless steel baseline. These results show that using terracotta separators to cut costs and CB-modified anodes for better stability can be a promising approach for improving wastewater treatment and energy recovery in bioelectrochemical systems. → *Session program*

Towards Sustainable Offshore Platforms: A Review on Energy Management Systems (EMS) for Grid connected offshore Energy Hub with BESS Integration

Segid Tedla, UiT The Arctic University of Norway

Abstract. The transition of offshore oil and gas (O&G) platforms into sustainable, grid connected off-

shore energy hubs require reliable, efficient, and resilient energy systems that can integrate high shares of renewable energy sources such as offshore wind and power from shore (PFS). However, power from offshore winds is inherently intermittent, while PFS solutions are limited by high capital costs and the thermal constraints of subsea cables. Among several emerging technical solutions to solve these challenges, Battery Energy Storage Systems (BESS) have gained significant attention in recent years. BESS have superior ability to mitigate renewable variability, enhance power quality, and support overall grid stability. Achieving these benefits, however, hinges on selecting an appropriate Energy Management System (EMS) capable of ensuring effective coordination and optimal operation of the offshore energy hub. Hence, this paper provides a comprehensive review of EMS approaches for grid connected offshore energy hubs integrating BESS. This paper also highlights state-of-the-art EMS strategies, control architectures, and optimization methodologies that enable efficient and sustainable offshore energy management. The review paper investigates relevant EMS frameworks, with particular emphasis on their ability to address key operational challenges, including wind variability, real time load balancing, and the growing role of artificial intelligence in real-time EMS. Additionally, the paper also examines how advanced EMS solutions enhance the economic performance of offshore energy hubs by facilitating, optimal energy mix, peak shaving, frequency regulation, techno- economic viability and participation in ancillary service markets. → *Session program*

Session on Geometry and Optimization

Session chairs: Cordian Riener and Rodolfo Ríos-Zertuche *→ Full program*

Session program

Monday	14:40-15:10	**Henriksen**
	15:15-15:45	**Arjmand**
	15:50-16:20	**Geleta**
Tuesday	14:40-15:10	**Lakså**
	15:15-15:45	**Jankowsky**
	15:50-16:20	**von Bargen**
Thursday	10:20-11:10	**Munthe-Kaas**
	11:10-11:40	**Kosmač**
	11:40-12:10	**Corona Sanchez**
	14:40-15:30	**Rouillier**
	15:40-16:10	**Vitrih**
Friday	10:20-11:10	**Ratsaby**
	11:20-12:10	**Mascarin**

Solving Elliptic PDEs in unbounded domains

Doghonay Arjmand, Uppsala University

Abstract. An accurate approximation of solutions to elliptic problems in infinite domains is challenging from a computational point of view. This results from truncating the domain and imposing artificial boundary conditions, which may introduce mod- eling errors in an interior region of interest. For elliptic problems with periodically varying coefficients (with a possibly unknown period), a modeling strategy based on an exponentially regularised elliptic problem was previously developed and analysed. The main idea was to replace the infinite domain periodic problem with a regularised elliptic problem posed on a finite domain, while retaining an accuracy decaying exponentially with respect to the size of the truncated domain. In this article, the analysis is extended to problems where no structural assumptions on the coefficient are made. We also identify a key property of the right-hand side in the Fourier domain that ensures rapid convergence of the method beyond the periodic setting. *→ Session program*

From Control Theory to Flight Software: An MBSE Approach for a Differential Drag Satellite Formation

Jose Juan Corona Sanchez, UiT The Arctic University of Norway

Abstract. Space missions impose strict reliability requirements, where even minor design errors can lead to severe consequences. Consequently, spacecraft control algorithms must undergo rigorous verification and validation (V&V) before deployment. This raises a key challenge: how can control algorithms developed and validated in simulation be reliably transferred to real spacecraft systems? Relative motion without propulsion can be achieved through differential drag, and the literature offers a broad range of control strategies for satellite formation flying. However, translating theoretical control laws into executable flight software remains nontrivial due to system nonlinearities, hardware constraints, and operational limitations inherent to space platforms. This work addresses this challenge within the CENSSAT-1 mission, whose primary objective is to demonstrate novel Norwegian technologies in orbit, including advanced sensor payloads and spacecraft control algorithms, and to validate their performance in a realistic space environment. Among its payloads, the Drag Control (DRACO) experiment aims to achieve relative positioning between the spacecraft and a virtual satellite using differential drag. The successful deployment of such strategies depends not only on control theory, but also on software architecture, hardware capabilities, and structured V&V processes that ensure spacecraft safety and mission robustness. To address this, DRACO adopts a three-layer V&V framework: (1) Hardware-in-the-Loop (HITL) testing as the lowest validation layer, (2) FlatSat system-level integration, and (3) full spacecraft validation as the highest qualification layer. In this work, a complete system architecture is

modeled using Model-Based Systems Engineering (MBSE). The MBSE framework supports the identification of credible faults, the construction of fault trees, and the design of recovery strategies, acting as an intermediate layer between the mathematical formulation of the control law and its implementation in the physical system. In addition, a dedicated verification platform is presented for the implementation, testing, and validation of a differential-drag-based formation control algorithm using a HITL methodology. The proposed approach spans the full development chain, from high-fidelity dynamic modeling of the spacecraft, space environment, and Earth's magnetic field, through control law design and software implementation, to integrated V&V activities aligned with ESA Phase B standards. Simulation and preliminary results demonstrate the applicability and robustness of the proposed framework.
→ *Session program*

Recent Trends in AI and Cybersecurity: A Mathematical Perspective

Hunduma Legesse Geleta, Addis Ababa University

Abstract. Artificial Intelligence (AI) and Cybersecurity are undergoing rapid transformation, with foundational mathematics playing a central role in both their development and defense mechanisms. This article surveys the evolving mathematical landscape that underpins recent advances in AI and cybersecurity, covering topics such as logic, optimization, algebra, geometry, probability, and theoretical computer science. → *Session program*

A direct slicing approach for additive manufacturing

Tanja Henriksen, UiT The Arctic University of Norway

Abstract. In a typical workflow for additive manufacturing (AM), the computer-aided design (CAD) model is first converted to a mesh representation. A slicing process is then performed on the mesh to obtain the layers needed for the tool-path generation. During this process, inaccuracies may occur, e.g. conversion error, lack of data, inaccurate data representation and error propagation. These errors may make the production model deviate from the intended design captured by the non- uniform rational B-spine (NURBS) model. Therefore, we introduce a method for slicing the CAD models in its boundary representation (BREP), aiming to present the NURBS representation as long as possible through the AM process. This direct slicing approach ensures a curve-based representation of the model compared the typical linear representation. With a curve-based representation intrinsic properties embedded within the curves are preserved. Access to these properties gives the ability to adjust important parameters, such as e.g. printing speed and extrusion rate, based on derivatives of the (parametrized) curves. Results from a slicer prototype will be showcased for several example models. → *Session program*

On Semidefinite Relaxations of MinCut and Modularity for Capacity-Constrained Clustering

Alina Jankowsky, Karlsruhe Institute of Technology

Abstract. Graph clustering and partitioning are fundamental tasks in combinatorial optimization and data analysis. However, incorporating strict operational limits, such as upper bounds on the total weight of nodes assigned to any single cluster, transforms the task into a computationally challenging capacity-constrained clustering problem. Heuristic approaches often fail to respect these capacity constraints during the clustering process, providing no mathematical optimality gaps and requiring post-hoc repairs.

This work presents an optimization-based framework to overcome these limitations. The capacity-constrained clustering problem is formulated as a unified Binary Quadratic Program (BQP). This formulation flexibly integrates MinCut and Modularity objectives to ensure structural cohesion and clear topological separation, while strictly enforcing capacity limits directly within the optimization process.

Given the NP-hardness of the exact BQP, the methodological core of this work focuses on developing tractable convex relaxations. Based on the theory of copositive programming, we derive semidefinite and linear relaxations. To solve these large-scale relaxations, two methods are used and benchmarked: primal-dual interior-point methods (MOSEK) and first-order augmented Lagrange methods (SCS). Furthermore, we develop dedicated rounding procedures to extract physically feasible, connected discrete clusters from the relaxed continuous solutions.

By combining the theoretical bound obtained from the relaxation with the objective value of the rounded discrete solution, the framework provides an optimality gap for the quality of the resulting partition.

The practical utility of these methods is demonstrated by their application to the generation of synthetic low-voltage (LV) electrical distribution grids. In this field, defining supply areas based on transformer capacities is a critical planning task. Evaluated on realistic network instances against established geometric standard methods (such as Ward's method), the proposed optimization approach provides a mathematically founded alternative. Within the scope of the tested scenarios, heuristic baselines remain competitive in urban areas, whereas the mathematical optimization framework provides superior, strictly capacity-compliant solutions in rural areas. Thus, the developed methods bridge the gap between theoretical graph clustering and the strict operational requirements of modern power grids.

→ *Session program*

An Isogeometric Tearing and Interconnceting (IETI) method for the polyharmonic equation of order m over planar multi-patch geometries

Aljaž Kosmač, University of Primorska

Abstract. We present a novel method for solving the polyharmonic equation of order m ($m \geq 1$), a particular linear elliptic partial differential equation (PDE) of order $2m$, over planar multi-patch geometries with possibly extraordinary vertices. Our proposed technique is based on the framework of Isogeometric Tearing and Interconnecting (IETI) [1], whose basic idea is to use Langrange multipliers to couple the numerical solution of the PDE across the edges of the multi-patch geometry with sufficient smoothness, that is in our case with C^s ($s \geq m-1$) smoothness. The use of Lagrange multipliers allows to formulate a saddle point problem, which is solved first by a small dual problem for the Lagrange multipliers followed by local, parallelizable problems on the single patches for the coefficients of the numerical solution. Moreover, the considered planar multi-patch domain is represented by a particular class of multi-patch geometries, the so-called bilinear-like G^s multi-patch parameterizations [2]. The potential of our IETI-based method for solving the polyharmonic equation of order m over planar multi-patch geometries is demonstrated on the basis of several numerical examples, especially for the case of the polyharmonic equation of order $m = 2$ and $m = 3$, i.e. for the biharmonic and triharmonic equation, respectively. Joint work with M. Kapl and V. Vitrih

[1] S. K. Kleiss, C. Pechstein, B. Jüttler, S. Tomar. IETI - Isogeometric Tearing and Interconnecting. Computer Methods in Applied Mechanics and Engineering, 247–248: 201–215, 2012.

[2] M. Kapl, V. Vitrih. C^s-smooth isogeometric spline spaces over planar bilinear multi-patch parameterizations. Advances in Computational Mathematics, 47: 47, 2021.

→ *Session program*

An interactive deformation technique for curves, surfaces, and volumes

Arne Lakså, UiT The Arctic University of Norway

Abstract. We will look at implementing new interactive "editing tools" for curves, surfaces and volumes for use in a graphics window on a screen. Any parametric curve, surface or volume can be made "editable" by adding a "B-spline structure". This means that we can easily change the shape by adding knot vectors corresponding to polynomial B-splines of degree 1. In each knot value that has a knot interval on its sides, we introduce a "point" that interpolates the geometric object, which has an orientation and a size, that is, it can be rotated and scaled. The "points" are actually homogeneous matrices. In each internal knot value we have, for a curve, a knot interval on each side. These two intervals form the domain of the matrix in the knot. At each knot interval we then have two matrices that are active. We then blend these two matrices with a blending function and get a matrix function with one parameter, which we then multiply by the original curve. For a tensor product surface, we have knot vectors in two directions and thus 4 matrices and 2 blending functions to generate a matrix function with two parameters, and for a volume 8 matrices and 3 blending functions to generate a matrix function with three parameters. The result is a smooth curve, surface or volume with control points that interpolate and can be rotated and scaled. The "points" can be displayed as cubes that can be manipulated interactively.

→ *Session program*

Lissajous Varieties

Francesco Maria Mascarin, MPI MiS & CWI

Abstract. We introduce Lissajous varieties as affine algebraic varieties parametrized by sine and cosine functions. They generalize algebraic Lissajous curves in the plane to higher dimensions by applying a componentwise trigonometric map to a rational affine linear space. We show that their degree (namely, the number of intersection points with a generic affine linear space of complementary dimension) can be computed from the volume of a corresponding polytope, and that their defining equations arise from rank constraints on an associated matrix encoding polynomial multiplication. We discuss their applications to dynamical systems in the study of equilibria, with a particular focus on the Kuramoto model. Here we explore their connections with convex optimization and Lissajous discriminants. Finally, in the context of semidefinite programming, we highlight the crucial role these varieties play in describing the algebraic boundary of the elliptope for certain graph classes. This is based on joint work with Monique Laurent and Simon Telen. *→ Session program*

Symmetry: From Classical Ornamentation to Computational Mathematics and Archimedes' Labyrinth

Hans Munthe-Kaas, UiT The Arctic University of Norway and University of Bergen

Abstract. Symmetry is a fundamental theme that has inspired artists and mathematicians from antiquity to the present day. Ornamentation is the art of creating patterns and decorative forms through the systematic repetition of a basic motif, such as frieze patterns, or borders, which repeat in one direction, and wallpaper patterns, or tessellations, which repeat in two directions. Other examples include symmetric patterns on Christmas baubles and M.C. Escher's ornamentation of hyperbolic space. Group theory is the mathematical language for studying symmetries. This is a particularly strong field in Norwegian mathematics, with Abel, Sylow, Lie, Selberg, and Selmer as internationally renowned figures.

The lecture gives a non-technical presentation of a fascinating interplay between art and mathematics. We will discuss the classification of friezes and wallpapers via John H. Conway's "Magic Theorem", and present a concrete example: Archimedes' Labyrinth, a mathematical hedge maze in the Botanical Garden in Bergen.

We will also outline some applications of symmetries and group theory in computational mathematics. *→ Session program*

Information-Theoretic Characterizations of Self-Similar Geometry

Joel Ratsaby, Ariel University

Abstract. Fractal sets combine simple generative rules with highly intricate geometric structure. This talk introduces an information-theoretic framework for quantifying such complexity through compression ratios and information density of planar sets. Using rational approximations based on Farey grids, we construct binary encodings of finite-resolution approximations and compare their compressed and uncompressed description lengths to measure the information required to describe the set, including the complexity contributed by its boundary. The method is fully combinatorial and differs from classical entropy or Kolmogorov complexity. Applications to canonical fractals, such as the Sierpiński gasket and the Koch snowflake, demonstrate how information density reveals descriptive features that are not captured by fractal dimension. *→ Session program*

Certified Symbolic-Numeric Algorithms for some Industrial Robotics Applications

Fabrice Rouillier, INRIA

Abstract. Many critical robotics applications, particularly parallel manipulators, rely heavily on solving complex systems of non-linear and polynomial equations. Driven by the strict certification and safety requirements of these domains, our work focuses on developing reliable mathematical algorithms to tackle these demanding industrial challenges. Purely numerical root-finding approaches, while computationally fast, often lack the rigorous error bounds necessary to certify a robot's kinematic behavior. Conversely, purely symbolic methods provide exactness but frequently suffer from prohibitive computational complexity when scaled to real-world problems. Furthermore, real-world systems inherently

involve physical uncertainties, such as manufacturing tolerances, which are notoriously difficult to incorporate into classical exact algebraic tools. To bridge this gap, we present a hybrid symbolic-numeric approach. Our algorithmic pipeline first relies on exact algebraic elimination techniques (Resultants, Gröbner bases, Rational Univariate Representations) to reduce the dimensionality of the initial systems. We then couple these symbolic representations with arbitrary-precision interval arithmetic, implementing validated numerical methods—including interval Newton algorithms and the Kantorovich theorem—to efficiently isolate real roots and track solution paths via continuation methods for safe robotic trajectory planning. → *Session program*

A C^s-smooth mixed degree and regularity isogeometric spline space over planar multi-patch domains

Vito Vitrih, University of Primorska

Abstract. We present the construction of a C^s-smooth mixed degree and regularity isogeometric spline space over planar bilinear-like G^s-smooth multi-patch domains, which possesses the degree $p = 2s + 1$ and regularity $r = s$ in a small neighborhood around the inner edges and vertices of patch valency greater than one, and the degree $\widetilde{p}$ with $s + 1 \leq \widetilde{p} \leq p$ with regularity $\widetilde{r} = \widetilde{p} - 1$ in all other parts of the domain. This approach allows to solve partial differential equations (PDEs) with a much lower number of degrees of freedom compared to employing the C^s-smooth spline space [1] with the same high degree $p = 2s + 1$ and regularity $r = s$ everywhere. The reduction of degrees of freedom is achieved by introducing an appropriate mixed degree and regularity underlying spline space over $[0, 1]^2$ to define the functions on the single patches. The potential of the constructed C^s-smooth mixed degree and regularity isogeometric spline space is demonstrated by several applications. Firstly, by solving the biharmonic and triharmonic equation via the isogeometric Galerkin method [2], secondly by performing isogeometric collocation based on mixed superconvergent collocation points for solving the Poisson's and the biharmonic equation [3], and finally, by using the C^s-smooth mixed degree and regularity space in the context of IETI methods for high order PDEs [4]. Joint work with M. Kapl and A. Kosmač.

[1]: M. Kapl, V. Vitrih. C^s-smooth isogeometric spline spaces over planar bilinear multi-patch parameterizations. Advances in Computational Mathematics, 47: 47, 2021.

[2] M. Kapl, A. Kosmač, V. Vitrih. A C^s-smooth mixed degree and regularity isogeometric spline space over planar multi-patch domains. Journal of Computational and Applied Mathematics, 473:116836, 2026.

[3] M. Kapl, A. Kosmač, V. Vitrih. Isogeometric collocation with smooth mixed degree splines over planar multi-patch domains. Computers & Mathematics with Applications, 210: 89-112, 2026.

[4] M. Kapl, A. Kosmač, V. Vitrih. An Isogeometric Tearing and Interconnecting (IETI) method for solving high order partial differential equations over planar multi-patch geometries. Computer Methods in Applied Mechanics and Engineering, 452: 118769, 2026. → *Session program*

Mathematical Models in AI and Data Science with a View toward Agrifood

Kevin von Bargen, Osnabrück University

Abstract. In recent years, several projects have been or are being carried out at Osnabrück University that lie at the interface between agricultural technology, the food industry and ai, data science as well as robotics. Interestingly, it is becoming increasingly clear that mathematical models are useful new methods to support these activities. On the other hand, problems related to these projects motivated questions about mathematical methods in data science and related areas. In this talk I will report on these activities and on some of the latest results. → *Session program*

Session on Industrial Applications and Mathematical Modeling

Session chair: Hassan Abbas Khawaja → *Full program*

Session program

Monday	10:30-11:20	**Boiger**
	11:30-12:00	**Gupta**
	14:40-15:30	**Patil**
	15:40-16:10	**Vaseem**
Tuesday	10:20-11:10	**Mustafa**
	11:20-11:50	**Kumar**
	14:40-15:30	**Nabi**
	15:40-16:10	**Upreti**

A Multiscale Simulation Framework for Spray Drying: Coupling System-Level Models, CFD, and Design-of-Experiments for Simulation-Driven Process Design

Gernot Boiger, ZHAW Zurich University of Applied Sciences

Abstract. Spray drying processes involve tightly coupled transport phenomena across multiple spatial and temporal scales, making their design, optimisation, and scale-up highly challenging. High-fidelity computational fluid dynamics (CFD) models provide detailed physical insight but are computationally expensive, whereas reduced-order models enable rapid evaluation but lack spatial resolution.

This work presents a multiscale simulation framework that systematically couples reduced-order system dynamics models with three-dimensional CFD simulations and design-of-experiments (DoE) methodologies for simulation-driven process design. A one-dimensional thermodynamic model enables rapid exploration of the global process space, while OpenFOAM-based CFD models resolve flow structures, droplet dynamics, and evaporation phenomena. An integrated Python workflow supports automated parameter studies and consistent mapping between process inputs and outputs.

Validation against experimental data demonstrates robust identification of dominant parameters and interaction effects across operating regimes, highlighting the ability of the framework to detect critical sensitivities beyond isolated modelling approaches.

A key perspective is the integration into the GPU-accelerated lattice Boltzmann method (LBM) platform SimVantage. This enables reduced computational cost while maintaining physical fidelity, supporting large-scale parametric studies, surrogate model development, and the advancement of physics-informed digital twins.

The framework provides a transferable approach for bridging high-fidelity simulation and industrial applicability in multiphysics process design. → *Session program*

Nonlinear Dynamics of Flexible Beams Subjected to Moving Inertial Loads using the Absolute Nodal Coordinate Formulation

Shakti Gupta, Indian Institute of Technology Kanpur

Abstract. This work presents a rigorous framework for analyzing the nonlinear dynamics of flexible beam structures subjected to traveling inertial loads. Addressing the limitations of classical linear theories and standard finite element formulations in handling large deformations and gross rigid-body rotations, the Absolute Nodal Coordinate Formulation (ANCF) is employed. A fully coupled equation of motion is derived using Hamilton's principle and the method of Lagrange multipliers, explicitly accounting for the time-varying interaction between the beam's elastic deformation and the traveling mass. The derivation rigorously isolates the inertial contributions into specific local, mixed (Coriolis-like), and convective (transport/centripetal) force vectors. A key advantage of this formulation is the preservation of a constant, symmetric system mass matrix, which significantly enhances computational efficiency compared to frame-dependent formulations. The resulting highly nonlinear system is solved using an implicit Newmark-β time integration scheme coupled with a Newton-Raphson iterative solver. The framework is validated through a hierarchical benchmark process: first, against semi-analytical Galerkin solutions for linearized moving force and moving mass problems; and second, against Geometrically Exact (GE) beam theory for a freely falling hanging beam undergoing large rotations. The results demonstrate that the proposed ANCF approach accurately captures geometric stiffening effects, inertial coupling, and energy conservation in high-speed, large-deformation scenarios. *→ Session program*

Modeling and simulation of low velocity impact on silica-based Shear thickening fluid impregnated Kevlar

Nitin Kumar, Indian Institute of Technology, Delhi, India

Abstract. A finite element-based micromechanical model of the response of Kevlar fabric to an impactor and to yarn pull-out has been developed in LS-Dyna. Micromechanical models are effective for capturing yarn-to-yarn interactions and can be used for virtual testing of fabrics. In this research, we have successfully synthesized monodispersed silica nanoparticles and developed formulations for shear thickening fluids (STF). Using experimental data from STF-impregnated Kevlar yarn-pullout and impact tests, a finite element model has been created. Experimental data on low-velocity impact resistance and yarn pullout were validated using micromechanical models. A parametric study was conducted to analyze various coefficients of friction for yarn pullout tests. *→ Session program*

Parametric Thermodynamic Analysis of a Turbine-Less SOFC–Brayton Hybrid Cycle for Hydrogen-Powered Aircraft Propulsion

Mohamad Mustafa, UiT The Arctic University of Norway

Abstract. This work presents a mathematical and thermodynamic parametric analysis of a novel turbine-less jet propulsion concept in which a solid oxide fuel cell (SOFC) is fully integrated with an open-cycle Brayton engine. In this configuration, the SOFC provides both the electrical power needed to drive the compressor and the high-grade thermal energy required for air heating, eliminating the turbine stage entirely and thereby simplifying the propulsion architecture. Motivated by the increasing environmental sensitivity of the Arctic atmosphere to long-lived aircraft emissions, the study focuses on the performance implications of hydrogen fuel in a high-efficiency, near-zero-carbon propulsion cycle. A set of governing equations for the combined cycle is formulated under the air-standard, constant-property, isentropic-compression assumptions. Using these analytical expressions, a systematic parametric investigation is conducted on key variables including compressor pressure ratio, SOFC electrical efficiency, thermal effectiveness of the fuel-cell heat exchanger, nozzle expansion ratio, and compressor inlet temperature. Sensitivity maps generated from the parametric sweep reveal that the overall cycle efficiency exhibits strong nonlinear dependence on compressor inlet temperature and SOFC efficiency, while maintaining quasi-linear dependence on pressure ratio within the 1.3–2 range typical of low-pressure aircraft compressors. The results show that the hybrid configuration can achieve overall efficiencies approaching 73% even under conservative SOFC efficiency assumptions (50%), significantly outperforming conventional gas-turbine-based propulsion systems. Because the compressor inlet temperature decreases sharply at cruise altitude, the parametric model predicts an additional intrinsic efficiency gain during high-altitude Arctic flight operations. These findings demonstrate that detailed parametric modelling offers an essential mathematical tool for designing next-generation, hydrogen-powered, low-emission propulsion systems. *→ Session program*

Numerical Prediction Of Kinetic Rate Constants and Sensitivity Analysis of High-Density Polyethylene Plastic Pyrolysis

Rao Adeel Un Nabi, Univeristy of Chinese Academy of Sciences, China

Abstract. The experimental determination and statistical prediction of kinetic rate constants are well established; however, their real-time implementation remains limited by the inability to integrate them within complex reaction mechanisms systematically. To address this gap, an inverse modelling framework based on target product yields of 50% oil and 50% gas at a simulated reaction time of 120 minutes, with an objective function that minimizes the squared deviation between the simulated and target yields, has been investigated using ordinary differential equations (ODEs). The investigation reveals a 28% increase in oil yield while preserving gas production. Sensitivity analysis ($\pm 100\%$) identified decreases in kinetic rate constants (k_2, k_5, and k_7) as the dominant parameters governing oil formation,

particularly during the intermediate and final stages of pyrolysis. Among all rate constants, k_9 exerted the greatest influence on both oil and gas yields, underscoring its critical role in HDPE chain scission and product distribution. These results demonstrate that inverse modelling enables systematic yield optimization beyond conventional experimental or statistical approaches. Moreover, sensitivity analysis provides mechanistic insight into the individual and coupled effects of kinetic parameters, highlighting the potential of this framework as a predictive and design-oriented tool for plastic recycling and thermal conversion processes. → *Session program*

Mathematical State-Space Formulation of Coupled Electromechanical Dynamics in a Moving-Magnet Linear Actuator

Aniket Chandrakant Patil, Walchand College of Engineering

Abstract. Moving-magnet linear actuators are widely used in precision electromechanical systems such as cryogenic compressors, active vibration control devices, and high-accuracy positioning mechanisms. This work presents a mathematical state-space formulation for the coupled electromechanical dynamics of such systems. The model integrates electrical circuit equations with mechanical motion dynamics, capturing the interaction between current, electromagnetic force, and system response. The governing equations are reformulated into a compact state-space representation, enabling systematic analysis of transient behaviour, stability, and parameter sensitivity. Numerical simulations are performed in MATLAB/Simulink to evaluate system performance under varying operating conditions. The proposed framework provides a rigorous basis for modelling and analysis of coupled electromechanical systems and can support further research in system optimization and control design. → *Session program*

FLOW DYNAMICS OF NANO-ENCAPSULATED PHASE CHANGE MATERIAL-BASED NANOFLUID OVER WEDGE USING PINN: APPLICATION TO THERMAL SYSTEMS

Himanshu Upreti, BML Munjal University

Abstract. Nano-encapsulated phase change material (NEPCM)-based nanofluids are increasingly employed in advanced thermal systems due to their combined latent heat storage and enhanced thermal transport capabilities; however, their three-dimensional flow behaviour over pressure-gradient geometries remains insufficiently explored. This work investigates the steady three-dimensional magnetohydrodynamic boundary layer flow and heat transfer of an NEPCM-based nanofluid over a wedge, incorporating thermal radiation, Hall and ion-slip effects, and Ohmic heating. The governing nonlinear transport equations are reduced using similarity transformation and solved using physics-informed neural networks (PINNs), in which the governing equations and boundary conditions are embedded into the loss function using automatic differentiation, enabling a mesh-free and data-independent computational framework. The effectiveness and accuracy of the applied approach are validated through comparison with established results available in the literature. The results indicate that increasing the ion-slip and Hall current parameters significantly suppresses both velocity components, leading to reduced wall shear stress; specifically, the transverse skin friction coefficient (SFC) decreases by approximately 20.4% with increasing ion-slip and 28.8% with increasing Hall current. The temperature slip parameter is found to markedly enhance the thermal performance, while variation in the wedge parameter demonstrates that larger wedge angles intensify axial SFC and heat transfer. These findings provide design-orientated insights relevant to advanced thermal management applications such as electronic cooling and high-temperature energy systems. → *Session program*

Wavelet-Based PINN Analysis of Melting Heat Transfer in NEPCM Flow over an Exponentially Stretching Cylinder

Mohd Vaseem, BML Munjal University, Gurugram, Haryana, India

Abstract. This study presents a comprehensive analysis of boundary layer flow and heat transfer over an exponentially stretching cylinder subjected to melting/solidification effects and enriched with nano-encapsulated phase change materials (NEPCMs). The flow is driven by an exponentially stretching

cylindrical surface, while the thermal transport is influenced by velocity slip, nonlinear thermal convection, and nonlinear thermal radiation. The working fluid consists of a nanofluid containing NEPCM particles with n-octadecane as the core material and Polymethyl methacrylate (PMMA) as the encapsulating shell, enabling enhanced latent heat storage within the flow domain. The melting phenomenon at the cylinder surface is incorporated through a Stefan-type boundary condition, introducing the melting parameter into the thermal model. The governing equations are transformed into a coupled system of nonlinear ordinary differential equations. To solve the resulting highly nonlinear system, a robust wavelet-based Physics-Informed Neural Network (PINN) is employed, ensuring accurate enforcement of both governing equations and boundary conditions. The numerical results demonstrate that increasing the melting parameter significantly suppresses the velocity and temperature fields, whereas higher curvature effects intensify momentum and heat transport by modifying the boundary layer structure. The interaction between surface stretching, melting, and NEPCM-induced heat absorption provides effective control over thermal performance. The present findings are highly relevant to the design of solar thermal energy storage systems, advanced heat exchangers, thermal management of cylindrical devices, and latent heat-based energy conversion technologies, where phase change and curved stretching surfaces play a critical role. → *Session program*

Session on Mathematics and Mathematical Modelling: Fourier Analysis and Optimization

Session chairs: Lars-Erik Persson and Natasha Samko *→ Full program*

Session program

Thursday	10:20-11:10	**Tephnadze**
	11:10-11:40	**Tutberidze**
	11:40-12:10	**Evgrafov**

Free-material optimization of peridynamic diffusion

Anton Evgrafov, Aalborg University

Abstract. Free-material optimization (FMO) is an optimal design paradigm in which the material constitutive tensor is treated as a pointwise design variable. This topic is by now well studied and provides rigorous bounds on achievable performance when the designer is constrained only by the most fundamental physical requirements, such as symmetry and definiteness, and not by homogeneity or isotropy.

In this talk, we consider FMO in a bond-based peridynamic setting. We ask how the properties of individual bonds in a bond-based peridynamic material should be chosen to achieve optimal performance. This formulation aligns naturally with the FMO philosophy.

Our focus is the classical optimal design problem of minimizing the complementary energy associated with a bond-based peridynamic diffusion operator. We analyze this problem within the FMO framework and study its behaviour in the limit of the nonlocal interaction horizon tending to zero.
→ Session program

Sharp strong convergence result of the two-dimensional Walsh-Fourier series in martingale Hardy spaces

George Tephnadze, The University of Georgia

Abstract. Unlike the classical theory of Fourier series which deals with decomposition of a function into sinusoidal waves the Walsh functions are rectangular waves. The research continued intensively also after this. Some of the most important steps in these developments are presented in the recent book by L. E. Persson, G. Tephnadze and F. Weisz from 2022. Weisz investigated strong convergence of partial sums $S_{m,n}$ of the two-dimensional Walsh-Fourier series in the martingale Hardy spaces, but under the condition when $2^{-\alpha} < m/n \leq 2^{\alpha}$. This talk is devoted to investigate strong convergence of the two-dimensional Walsh-Fourier series in the martingale Hardy spaces $H_p^{\square}(G^2)$ for $0 < p < 1$, without any restriction on the indices. Moreover, sharpness of this result is also showed. *→ Session program*

Linear functionals on Banach spaces and their applications

Giorgi Tutberidze, The University of Georgia and Tbilisi State University

Abstract. In this talk, we investigate the linear functionals with special face on the Banach space of functions from the Lipschitz class (C_L). By studying the boundedness of the sequence of these functionals, we establish conditions under which the Cesàro sums of general Fourier series of functions with derivatives from the Lipschitz class (C_L) with respect to general orthonormal systems are bounded. We also note that, in general, the Cesàro sums of functions of this class are not bounded. The results obtained are best possible. This research opens up new avenues for further exploration in functional analysis, particularly in understanding the interplay between Lipschitz continuity and Fourier series convergence. Future work may involve extending these findings to other classes of functions, potentially revealing deeper insights into the structure of function spaces. *→ Session program*

Session on Mathematics and Mathematical Modelling: Homogenization

Session chairs: Lars-Erik Persson and Natasha Samko → Full program

Session program

Tuesday	10:20-11:10	**Braides**
	11:10-12:00	**Piatnitski**
	14:40-15:30	**Panasenko**
	15:40-16:10	**Nedic**

Non-local effects in multi-scale homogenization

Andrea Braides, University of Rome Tor Vergata and SISSA, Trieste, Italy

Abstract. I will present some classes of multi-scale problems for oscillating energies where the usual optimization of oscillations giving homogenization coexists with concentration or averaging. This may occur in concentration problems with singularities or in perforated domains, in phase-transition problems, or in homogenization problems for long-range or discrete structures. → Session program

Operator representations of Herglotz-Nevanlinna functions

Mitja Nedic, Jönköping University

Abstract. Herglotz-Nevanlinna functions are holomorphic functions on the (poly-)upper half-plane that have non-negative imaginary part. Both in one and several variables, these functions have a wide variety of interpretations and applications, within fields such as perturbation theory, probability, convex optimization or electromagnetics to name a few. In this talk, we will discuss some recent results regarding operator representations of these function, i.e. ways to write the value of a function using resolvents of (possibly multivalued) self-adjoint linear operators. Based on joint work with Erik Avelin.
→ Session program

Partial dimension reduction for non-stationary Navier-Stokes equations in thin tube structures

Grigory Panasenko, Vilnius University

Abstract. The non-stationary Navier-Stokes equations in a thin tube structure, with no slip boundary condition, are considered. A new method of partial asymptotic dimension reduction is introduced and justified by an error estimate. This method reduces the problem to a one-dimensional equation on the graph and several decoupled full dimension problems in small domains. The full dimension problems are independent and can be solved by parallel computing. The talk presents the forthcoming paper G.Panasenko, K.Pileckas, Hybrid dimension modeling for Navier-Stokes equations in thin tube structures, Journal of Computational and Applied Mathematics, 482, 2026, 117257. → Session program

Homogenization of non-autonomous convolution type parabolic equations

Andrey Piatnitski, UiT The Arctic University of Norway

Abstract. The talk will focus on homogenization problems for nonlocal convolution type parabolic operators with coefficients which are rapidly oscillate both in the spatial variables and in time. We will show that in the periodic setting the homogenized problem is that for a heat equation. For non-symmetric operators the homogenizatiuon result holds in moving coordinate. We will also consider equations describing random stationary evolution of a periodic microstructure. In this case, under additional mixing conditions, the homogenized equation is a SPDE with a finite-dimensional multiplicative noise.
→ Session program

Session on Mathematics and Mathematical Modelling: Mathematics

Session chairs: Lars-Erik Persson and Natasha Samko → *Full program*

Session program

Tuesday	10:20-11:10	**Sawano**
	11:10-11:40	**Yeshitla**
	11:40-12:10	**Bocci**
Wednesday	10:20-11:10	**Samko**
	11:20-12:10	**Jain**
Thursday	14:40-15:10	**Yagoubi**
	15:15-15:45	**Asfaw**
	15:50-16:20	**Asif**
Friday	10:20-11:10	**Turčinová**
	11:10-11:40	**Ågotnes**
	11:40-12:10	**Londoño Orozco**

Modelling Guinea worm disease: mathematical approach

Manalebish Debalike Asfaw, Addis Ababa University

Abstract. Guinea worm disease is a parasitic infection caused by drinking water contaminated with water fleas. Most of the patients are adult males who had possibly drunk contaminated water in farming activities. The fact is that GWD is not just a disease of poverty, but rather a cause of poverty due to the disability and psychological causes.To identify major factors that contribute to eradication of the disease, SEIW model is used to describe the interactions among humans and guinea worms. The model is then analyzed mathematically for wel-posedness, equilibrium analysis and the basic reproductive number is obtained. In addition, a stability analysis of the disease free-equilibrium and endemic equilibrium are done. In this paper numerical simulation are also conducted to show the dynamics over time. Parameter sensitivity to the basic reproduction number was carried out to determine the contribution each parameter individually. From this we obtained a result that the combination of chlorination, filtration and education proves to be a promising intervention. The most effective way to eradicate GWD is to reduce the parasite birth rate this can be achieved by education. The paper analyzes key parameters to determine effective combinations of intervention. The result shows that reducing the parasite birth rate is more effective than water treatment. → *Session program*

Trajectory-Free Parameter Estimation in Interacting Particle Systems via Topological-Frequencies

Mu'izz Asif, University of Bristol

Abstract. Particle Tracking Velocimetry (PTV) contains an expensive computational bottleneck in its frame-to-frame matching step once targets are identified. This process is typically used to attain statistical physics metrics or infer system parameters, such as interaction law exponents. Persistent homology, a tool of Topological Data Analysis is used to capture high-level information of connectivity and voids in data at multiple spatial scales. Over time, the captured multiscale profiles can present structural evolution in the form of CROCKER vectorisations. This research offers an alternative topologically-driven methodology to estimate and compare system parameters and physical metrics without requiring complete particle trajectories, tested on electric-like synthetic data with a wide parameter mesh. This frequency analysis approach on the (Betti) CROCKER vectorisations, enables understanding of the different rates of topological variations of a confined system, directly embedding temporal information compared to treating it as a tuneable hyperparameter. This inherits stability from the frequency transform to large frame rate differences. We present a progression of interpretable metrics (from spectral peak characteristics to whole-spectrum) on this topological-frequency spectra that are able to characterise the system at multiple time and spatial scales, shown by using low-compute regression models to be able to estimate particular properties to a high accuracy (some with <7% mean absolute percentage error), as well as be able to predict relative differences between systems (some >90% accuracy).

These results show the capacity for TDA to interpret highly-coupled dynamical systems without resolving individual particle trajectories, offering a powerful and efficient alternative to traditional tracking methods.
→ *Session program*

Coupled Orbit–Attitude Control via Direct Torque Regulation of the Effective Surface

Alessio Bocci, UiT The Arctic University of Norway

Abstract. The spacecraft's effective surface (ES) is the area directly interacting with the atmosphere-spacecraft relative velocity vector. It is the only surface capable of generating drag acceleration and thus, its regulation is the most crucial aspect of drag-based orbital control (DBOC). DBOC is employed with propulsionless CubeSats and has been extensively studied in recent decades due to its effectiveness and low onboard implementation cost. The strategies reported in the literature provide a desired ES profile, which must be actuated either using drag panels or, more often with CubeSats, via attitude maneuvers. Existing control approaches mainly rely on a two-stage orbit-attitude design. This separation works fine for large spacecraft equipped with thrusters for which DBOC can serve as an additional resource, as in coarse station-keeping. However, this assumption becomes less realistic for CubeSats where atmospheric drag is usually the primary means of control, and therefore requires a coupled orbit-attitude formulation. The ES is a continuous function of the attitude variables but is not globally continuously differentiable. However, there are subsets of the domain where it is regular. Here, the ES dynamics can be controlled in two ways, either with an angular-velocity-based approach or with a direct torque-based approach. In this work, we design a coupled orbit–attitude controller using a direct torque approach. To the best of our knowledge, this technique is not present in literature and constitutes the main novelty of this work. The paper is structured as follows. First, the definition of the ES is established. Subsequently, domain restrictions are introduced, and the set of spacecraft configurations for which the ES is continuous and n-times continuously differentiable is defined. Within these regions, the second-order dynamics of the ES is derived. For each configuration, a torque-based controller is designed and the proof of asymptotic stability of the orbit–attitude closed loop system equilibrium points is provided. A key aspect is the constrained minimization problem used to determine the optimal control torque profile, while simultaneously guaranteeing forward invariance of the configuration. Finally, numerical simulations in realistic orbital scenarios are presented to evaluate the performance of the proposed control system and demonstrate its effectiveness.
→ *Session program*

Hardy Type Linear and Bilinear Operators in Lebesgue Spaces

Pankaj Jain, South Asian University

Abstract. We shall present the results related to the Hausdorff operator

$$H_\phi g(x) = \int_0^\infty \frac{\phi(y)}{y} g\left(\frac{x}{y}\right) dy$$

which includes the Hardy operator besides many other well known operators and the bilinear Hardy operator

$$H(f,g)(x) = \left(\int_0^x f\right)\left(\int_0^x g\right).$$

Various variants of these operators will be presented and their boundedness in the framework of Lebesgue spaces will be discussed. Wherever possible, the bilinear operators will also be discussed in the discrete framework setting.
→ *Session program*

Spacecraft Inter-Satellite Distance Regulation Via Differential Drag Using Relative Orbital Elements

Mariana Londoño Orozco, UiT The Arctic University of Norway

Abstract. The growing deployment of small satellites in Low Earth Orbit (LEO) has increased interest in propellantless actuation methods. Differential drag enables passive control of relative motion. It works by modulating the satellites' effective surface (ES), which is the cross-sectional area facing the atmospheric flow. This creates relative accelerations that achieve and maintain desired spacecraft formations. The traditional mathematical framework is the Hill-Clohessy-Wiltshire (HCW) Cartesian model, which poorly captures perturbation effects. The current literature shows that the Relative Orbital Elements (ROE) are highly geometrically intuitive and can efficiently model perturbed motions. Therefore, a significant research gap is the development of new ROE-based differential drag control algorithms. This paper develops a mathematical framework for a leader–follower formation scheme based on D'Amico's ROE model, incorporating differential drag and the ES difference as the control input. This work compares the proposed ROE framework with the HCW formulation in terms of accuracy and fidelity in representing perturbed relative motion. Both models are then benchmarked against the solution of the coupled nonlinear two-body problem to assess their ability to capture the relative dynamics under differential drag and other perturbations. To regulate the inter-satellite distance, a control law is synthesized in the ROE domain. The controller modulates the ES difference, which adjusts the net difference in drag acceleration between the two spacecraft. We present several simulations to validate the ROE-based control algorithm in various LEO mission scenarios. The results include uncertainty in atmospheric density variability and evaluate its impact on controller stability. → *Session program*

TBA

Natasha Samko, UiT The Arctic University of Norway, Narvik

Abstract. TBA → *Session program*

Morrey spaces

Yoshihiro Sawano, Chuo University

Abstract. This is an introduction of Morrey spaces based on my book on Morrey spaces.→ *Session program*

Interpolation of classical Lorentz spaces measuring oscillation

Hana Turčinová, Czech Technical University in Prague

Abstract. We will present an explicit characterization of the K-functional of a pair of certain specific weighted classical Lorentz spaces. Our method is based on a fine analysis of relevant fundamental functions and on relating the desired quantity to the K-functional of a more manageable couple of spaces. As an application we get an inequality of the reverse Marchaud type. This is a recent joint project with A. Gogatishvili, J. Neves and L. Pick. → *Session program*

A formel modelization of shakiness using Fourier Transform

Mohamed Riad Yagoubi, Inland University of Norway

Abstract. Camera shakiness remains a fundamental challenge in video acquisition, often introducing undesirable temporal jitter that propagates nonlinearly into the frequency domain. This paper presents a compact mathematical model describing video shakiness as an impulsive perturbation in time, represented by a sum of Dirac delta functions. Using the 3D Fourier transform of a video signal $F(x, y, t)$, we analyze how these impulses affect both the magnitude and, most importantly, the phase of the spatiotemporal frequency spectrum. Our analysis reveals that temporal jitter generates structured, frequency-dependent phase ramps that serve as identifiable signatures of shakiness. We further derive a computational algorithm for detecting such artifacts, based on phase residual analysis in the temporal frequency domain. The framework is theoretically grounded yet lightweight enough for practical stabilization and diagnostic applications. → *Session program*

Analysis of Unhealthy Attitude on Marriage and its Impact on the Dynamics of Divorce using Mathematical Model in the Case of Hawassa City

Etsehiwot Yeshitla, Wachemo University

Abstract. Divorce is the dissolution of two partners marriage, which is a serious problem challenging the establishment of the family in a routine manner and causing severe impacts on the emotional and mental health of the individual. A mathematical model that describes the spread of unhealthy attitude on marriage and its impact on the dynamics of divorce is proposed using a system of non-linear ordinary differential equations. The basic reproduction number R_0 is calculated using next generation matrix operator. The unhealthy attitude free equilibrium point is both locally and globally stable if $R_0 < 1$, and the unhealthy attitude present equilibrium point is also both locally and globally stable if $R_0 > 1$. The modified model exhibits a forward bifurcation whenever $R_0 < 1$, which indicates the threshold parameter plays an important role in reducing the spread of unhealthy attitude on marriage. Secondary data sources for divorce case were collected from Hawassa first instance court. The data were fitted to the model to estimate some parameter values using least square optimization method. Sensitivity analysis was performed to identify parameters which are sensitive to the reproduction number. According to this the contact rate between married and individuals who have unhealthy attitude β_1 and the rate of transfer from unhealthy attitude to healthy counseling ϕ plays an important role in reducing R_0 less than unity. Finally, we performed numerical simulations using ODE 45 codes to support the analytical results in agreement with numerical solutions. *→ Session program*

A Review of Convexity in 3D printing

Joachim Jørgensen Ågotnes, The Arctic University of Norway

Abstract. Convexity is a fundamental concept in geometry and analysis with deep theoretical and applied significance. In this paper, we revisit classical notions of convex sets and convex functions and introduce new convexity perspectives motivated by layer-wise additive manufacturing. Fused Deposition Modeling (FDM) provides a concrete three-dimensional setting in which convexity, non-convexity, and concavity directly influence toolpath topology, thermal continuity, and mechanical performance. By connecting classical results, such as Carathéodory's theorem in $\mathbb{R}^3$, with new layer-wise convexity concepts, we demonstrate how additive manufacturing constitutes a rich application domain for modern convexity theory. *→ Session program*

Session on Mathematics and Mathematical Modelling: Modelling and Statistics

Session chairs: Lars-Erik Persson and Natasha Samko → *Full program*

Session program

Monday	10:30-11:20	**Konjik**
	11:20-11:50	**Birdac (Fildan)**
	11:50-12:20	**Enerbäck**
	14:40-15:30	**Kaslik**
	15:30-16:20	**Nguyen**

Stability of equilibria in an infinite dimensional network of theta neurons with time delay

Lavinia Florina Rodica Birdac (Fildan), West University Timisoara, Romania

Abstract. We consider an infinite network of identical theta neurons, all-to-all coupled via instantaneous synapses, modelled through a system of differential equations with distributed delay. By applying the Watanabe–Strogatz ansatz transformation, Laplace transform of delay kernel, linearization and characteristic equation we conduct a detailed stability analysis of the equilibria, taking into account the effects of distributed delays. Our results show that the introduction of delay can lead to significant changes in the dynamical behaviour of the system, including the emergence of new bifurcations not present in the delay-free case. The analytical results are supported by numerical simulations, which also uncover complex patterns of neural activity shaped by the delay. → *Session program*

Computation of low rank approximations of matrix polynomials using regularization

Jenny Enerbäck, Chalmers tekniska högskola

Abstract. Polynomial eigenvalue problems are a well-known and extensively studied problem in mathematics. Theories and tools developed to solve these problems are among the most important contributions of mathematics to technology, engineering, and physics. However, novel developments in modern technology and advanced engineering increasingly require accurate and efficient solutions to new and challenging eigenvalue problems, e.g, singular eigenvalue problems (originating from low-rank approximations or involving rank-deficient structures due to the modeling techniques employed). Applying standard methods designed for nonsingular cases to singular problems can lead to catastrophic errors—computed eigenvalues may be entirely incorrect, dominated by round-off effects. Moreover, existing tools typically cannot provide warning that the results may be unreliable. Introducing a singularity check before solving an eigenvalue problem may not be enough to determine the reliability of the results, since small perturbations, coming from uncertainties in data or round-off errors, almost always transform a singular problem to a nonsingular problem. Consequently, a robust way to evaluate reliability of the computations is itself a challenging problem. One way to tackle it is computing a distance to singularity, i.e., the norm of the smallest perturbation that will make our problem singular. Recently a few algorithms, relying on completely different ideas, were developed to compute this distance but the problem remains challenging, in particular, for the polynomials of large size. In the presentation, we propose a new algorithm for approximating a given matrix polynomial with another matrix polynomials of rank at most r and also compute the distance from this given matrix polynomial to the computed approximation. Note that the "distance-to-singularity" problems is included here when the rank is chosen to be one less than the size. We use regularization techniques and build on a recently developed algorithm which in turn is using generic eigenstructures, their parametrizations, and an alternating least squares scheme. In a similar way, we also cover the case of skew-symmetric matrix polynomials. In preliminary tests, our algorithm is typically faster than the state–of–the–arts methods, while showing a similar accuracy, for both the skew-symmetric and general problems. This allows us to handle problems of larger size, as well as multiple starting guesses for small–to–medium size problems. → *Session program*

Stability and Bifurcation Structure of Wilson-Cowan Networks with Distributed Delays

Eva Kaslik, West University of Timisoara, Romania

Abstract. A network of N coupled Wilson-Cowan units with distributed transmission delays is studied. Each node contains interacting excitatory and inhibitory subpopulations, and inter-node coupling is encoded by weight matrices that specify the strengths of connections across the network. Distributed delays are incorporated through convolution terms with nonnegative kernels, describing the delay distribution on the corresponding connection. The analysis is developed first for two-node networks and then extended to general N-node architectures. Under the assumption of a homogeneous delay distribution, the linearization about equilibria yields a characteristic equation in which the network structure enters through the spectral properties of the coupling operators, enabling stability conditions and Hopf bifurcation thresholds to be expressed in terms of connectivity eigenmodes and the Laplace transform of the delay kernel. This setting provides architecture-independent conclusions that isolate how the shape of the delay distribution (beyond its mean) modifies stability boundaries and oscillation frequencies. The framework is then generalized to heterogeneous kernels, where delay variability across edges breaks the modal decoupling and alters the bifurcation set. As an application, the model is parameterized to reproduce abnormal oscillatory activity relevant to Parkinsonian dynamics, illustrating how changes in coupling strengths and delay distributions can generate or suppress pathological rhythms via delay-induced Hopf bifurcations. *→ Session program*

On controllability results for nonlinear fractional systems with applications

Sanja Konjik, Faculty of Sciences, University of Novi Sad

Abstract. This study addresses a terminal control problem for processes governed by a nonlinear system of fractional ordinary differential equations involving the Caputo derivative. To establish the existence of admissible controls for the nonlinear system, we first analyze the corresponding linear fractional system and extend several classical results from control theory to the fractional framework. In particular, we derive a representation of the solution using a Gramian-type matrix and obtain controllability conditions analogous to those known for integer-order systems. Within this framework, we also verify a fractional counterpart of Kalman's principle and demonstrate the equivalence between controllability and observability for the associated adjoint system. Building on the results for the linear case, the nonlinear problem is investigated using a fixed-point approach combined with tools from fractional calculus. This approach allows us to prove the existence of controls that steer the nonlinear system to a prescribed terminal state. The theoretical results are illustrated through numerical examples motivated by applications in biomedical modelling, particularly in cardiology, highlighting the potential relevance of fractional control models in medical contexts. *→ Session program*

Macroeconomic nowcasting with heavy-tail mixed-frequency VARs

Hoang Nguyen, Linköping University

Abstract. The mixed-frequency VAR model has become a workhorse for nowcasting low-frequency macroeconomic variables using the most recent release of information on related high-frequency variables. However, assuming Gaussian innovations may lead to biased estimations in the presence of outliers. In this paper, we propose an MF-VAR model with orthogonal Student-t distributions that accounts for the individual outliers in each VAR equation. Using the U.S. data for a small VAR setting, we show that the heavy-tailed distribution delivers more accurate nowcasting and forecasting for the quarterly GDP growth. It also improves the nowcasting of monthly variables and provides a solution to the contaminated estimations caused by the extreme observations of the Covid-19 pandemic. *→ Session program*

Session on Mathematics and Mathematical Modelling: Scientific Computing

Session chairs: Lars-Erik Persson and Natasha Samko

→ Full program

Session program

Wednesday	10:20-10:50	**Uddin**
	11:00-11:30	**Nylund**
	11:40-12:10	**Rodriguez Velasco**

Point inversion for spline curves on surfaces

Dag Nylund, University of Inland Norway

Abstract. We present spline curves and offset curves on tensor product surfaces and show examples of motion planning, simulations and CNC programming. A parametric curve c(t) on a surface S can be constructed by mapping a curve h(t) in the domain U of S, on S. There exists algorithms for the construction of this kind of B-spline curves on surfaces and their arc length parametrization. Here we look closer on point inversion problems, smoothness and approximation properties of the reparametrized curves. The initial construction of the curve h in U can be performed by using point inversion methods. The standard method to perform point inversion for this kind of surfaces is by using Newton's method, where the convergence depends on the initial guess. Parametrization by arc length can also be applied. We modify existing methods by taking advantage of the curve's properties and constraints.

→ Session program

A structure-preserving numerical scheme for compressible Resistive-Hall-MHD system

Rafael Rodriguez Velasco, Uppsala University

Abstract. We extend a previously developed structure-preserving method for the compressible ideal Magnetohydrodynamics (MHD) equations to the Hall resistive MHD model. The formulation is presented in a non-divergence formulation of the model, consisting of a compressible Euler's equation solver and a momentum-magnetic source system with a mechanical energy update. The magnetic field is discretized in a curl-conforming finite element space, ensuring the involution constraint. The scheme preserves positivity of density, internal energy, conservation of total energy, and the minimum principle for specific entropy. We assess the accuracy of the method using whistler waves and present reference computations of the GEM Magnetic Reconnection Challenge and Orszag–Tang vortex. The method uses residual-based resistivity, which allows us to show stability of the scheme across various mesh configurations while preserving the qualitative dynamics and reconnection rates. The resulting method provides a robust and consistent structure-preserving framework for Hall MHD.

→ Session program

A Novel Physics-Informed Optimal Homotopy Analysis Method (PI-OHAM) for Nonlinear Differential Equations

Ziya Uddin, BML Munjal University, Gurugram, India

Abstract. We present the Physics-Informed Optimal Homotopy Analysis Method (PI-OHAM) for solving nonlinear differential equations. PI-OHAM, based on classical HAM, employs a physics-informed residual loss to optimize convergence-control parameters systematically by combining data, boundary conditions, and governing equations in the manner similar to Physics Informed Neural Networks (PINNs). The combination of the flexibility of PINNs and the analytical transparency of HAM provides the approach with high numerical stability, rapid convergence, and high consistency with traditional numerical solutions. PI-OHAM has superior accuracy-time trade-offs and faster and more accurate convergence than standard HAM and PINNs when applied to the Blasius boundary-layer problem. It is also very close to numerical standards available in the literature. PI-OHAM ensures analytical transparency

and interpretability by series-based solutions, unlike purely data-driven or data-free PINNs. Significant contributions are a conceptual bridge between decades of homotopy-based analysis and modern physics-inspired methods, and a numerically aided but analytically interpretable solver of nonlinear differential equations. PI-OHAM appears as a computationally efficient, accurate and understandable alternative to nonlinear fluid flow, heat transfer and other industrial problems in cases where robustness and interpretability are important. → *Session program*

Session on Structural Health Monitoring of Civil Engineering Structures and Infrastructures

Session chairs: Vanni Nicoletti and Per Johan Nicklasson → *Full program*

Session program

Monday	10:30-11:20	**Storni**
	11:20-11:50	**Spina**
	11:50-12:20	**Patel**
	14:40-15:10	**Petrich**
	15:10-15:40	**Berg**
	15:40-16:10	**Schlanbusch**
Tuesday	10:20-11:10	**Quarchioni**
	11:10-11:40	**Bayazid**
	11:40-12:10	**Nwamma**
	14:40-15:30	**Bjerknes**
	15:40-16:10	**Mohammadreza**

Design and Simulation of an Arctic-Resilient Structural Health Monitoring System Using Optimal Sensor Placement: A Case Study of the Skattørsund Bridge, Norway

A K M Bayazid, Technipfmc Norge AS

Abstract. Maintaining aging infrastructure in remote Arctic areas presents unique challenges that require secure, reliable, and economically feasible real-time monitoring solutions to ensure a safe transportation system. This research outlines the design and simulation of a permanent Structural Health Monitoring System (SHMS) for the Skattørsund Bridge in Troms Fylke Kommune (TFK), Norway. The primary objective of this study is to address the critical issue of designing sensor networks that achieve optimal monitoring capabilities while considering financial constraints and the harsh Arctic environment. A high-fidelity finite element (FE) model of the bridge informs an automated optimal sensor placement (OSP) strategy, extracting modal properties. A custom-developed Python framework integrates FE-based modal analysis with advanced OSP algorithms, enabling rapid evaluation of candidate sensor configurations, comparing the Effective Independence (EFI) method with a hybrid Effective Independence–Driving Point Residue (EFI-DPR) approach. The findings show that the hybrid approach reduces off-diagonal Modal Assurance Criterion (MAC) values by prioritising energetically significant degrees of freedom. The proposed SHMS architecture uses piezoelectric accelerometers and a daisy-chained data acquisition system (DAS) topology intended for remote, low-maintenance deployment to guarantee long-term operability in Arctic conditions and facilitate ongoing monitoring of dynamic structures. The methodology and software tool developed provide an overall framework that can be used for OSP and a monitoring system to demonstrate SHMS on other civil structures, particularly in the remote Arctic environments. → *Session program*

Beam-based finite element modelling of Herøysund Bridge in Norway

Patrick Norheim Berg, Leirvik AS

Abstract. This paper gives a thorough insight into the modelling of two finite elements models of the post tensioned concrete Herøysund bridge. First a solid element model is made using the documentation from the bridge construction, then a beam element model is modelled using the solid model as a foundation. These models are subjected to a structural analysis that applies boundary conditions, joints, mass, gravity, asphalt, railings, and the post tensioning system. Then the structural analysis is used as a pre-stress condition for a modal analysis on each model. The modal analysis is used to find the eigenfrequencies and corresponding mode shapes of the bridge models. Interesting results from both models' analyses is compared to reveal how similar the models are and which model gives the most reliable results. The modes are compared using the modal assurance criterion. The modes are then evaluated, and significant modes are suggested for comparison with operational modes later. → *Session program*

Arctic Test Arena - If it works here, it works anywere

Ann Kristin Bjerknes, Norwegian Railway Directorate

Abstract. The Arctic Test Arena (ATA) on the Ofotbanen and Malmbanan railway corridor was officially launched in November 2025 as a Nordic cross-border test arena for railway technology. The corridor between Norway and Sweden offers a unique combination of Arctic climate conditions, heavy freight operations and demanding topography, making it an ideal environment for testing and validating new technologies before large-scale deployment.

ATA enables testing, demonstration and research under real operational conditions, supporting the development of more reliable, safe and resilient railway systems. Technologies related to infrastructure monitoring, predictive maintenance, digitalization, climate resilience and autonomous systems can be tested directly in live railway operations.

The initiative is built on strong Nordic collaboration between the Norwegian Railway Directorate, Bane NOR, Trafikverket, UiT – The Arctic University of Norway, Luleå University of Technology and SINTEF, and supports research and innovation within European railway programmes.

Within the first months after launch, the arena has already received multiple test and research requests from national and European actors, demonstrating the demand for testing technologies in real and challenging environments.

Arctic Test Arena illustrates how collaboration between infrastructure managers, research institutions and industry can accelerate innovation and reduce risk in the deployment of new railway technologies.

If it works here – it works anywhere. → *Session program*

Development of Digital Twin of the Herøysund Bridge using Finite Element Model Updating

Mohammadreza, UiT The Arctic University of Norway

Abstract. The aging of civil infrastructure presents significant challenges in a global scale, necessitating innovative research techniques for effective solutions. Governments are increasingly compelled to allocate additional time and budgetary resources towards maintenance, repairs, or the construction of new structures to replace deteriorated or damaged ones. This allocation is essential to ensure the provision of adequate services to citizens. Implementing a digital twin of any structure can help for Structural health monitoring. This thesis is aimed to build a digital twin of Herøysund Bridge. Vibration data obtained from the field work is used for finite element model updating. Updated finite element model is more similar to the real world behaviour of the bridge. In this thesis, a comprehensive literature review is carried out on various methodologies, including experimental modal analysis, operational modal analysis, and finite element modal updating. Furthermore, a genetic optimization algorithm is used for the finite element model updating of the shell-based model of the Herøysund Bridge using Matlab. The process of finite model updating, using a genetic algorithm, demonstrates promising results for the parameters updated. → *Session program*

Review and Application of Optimal Sensor Placement Method on Heroysund Bridge

Macdonald Nwamma, UiT The Arctic University of Norway

Abstract. This paper examined the optimal sensor configuration for modal identification on the Herøysund Bridge. It focused on minimizing the number of sensors utilized in determining the dynamic characteristics of the bridge during structural testing thereby positively impacting sensor system cost. This research systematically investigated several optimal sensor placement (OSP) methods for modal identification on the heroysund bridge. However, the Effective Independence method (EFI) was selected and applied to two finite element beam models designed on ANSYS, one with post-tensioned strands, and the other, without any post-tensioned strands. To facilitate this, the model data generated was fed as input data into a MATLAB algorithm developed based on this method. Similarly, a modified methodology, the Effective Independence Driving Point Residue (EFI-DPR) method, was introduced, and in the same way, an algorithm was developed for the optimization of sensor placement. The effectiveness of the sensor network generated was quantitatively validated using major performance metrics

such as the condition number, trace, and determinant of the Fisher Information Matrix (FIM). The results from the comparative study show that the EFI-DPR method outperforms the regular EFI approach for the bridge, ensuring that active modes which make significant contributions are fully captured in the sensor configuration, and uncertainties of estimated parameters greatly reduced. *→ Session program*

Integrated Experimental and Numerical Study for Early Detection of Carbonation-Induced Damage in Reinforced Concrete

Ajay Singh Patel, Shiv Nadar Institution of Eminence Deemed to be University

Abstract. Carbonation is one of the major causes of deterioration in reinforced concrete structures, significantly affecting their durability and long-term performance. The carbonation process reduces the alkalinity of concrete, leading to the loss of the protective passive layer surrounding the reinforcing steel and initiating corrosion. Such corrosion gradually weakens the structural capacity of reinforced concrete members. In this study, the influence of carbonation on reinforced concrete was investigated using non-destructive testing techniques along with finite

element analysis. Cylindrical concrete specimens containing embedded steel reinforcement were prepared and subjected to accelerated carbonation conditions. Electrical wires were connected to the reinforcing steel to measure corrosion activity through the half-cell potential method. Surface-bonded circular PZT patches were attached to the concrete specimens to monitor material degradation using the electro-mechanical impedance (EMI) technique. Admittance signatures obtained from the PZT patch were recorded continuously over a period of 50 days. The progression of deterioration during carbonation exposure was evaluated through both half-cell potential measurements and conductance signatures. In addition to the experimental

investigation, finite element analysis was carried out using ANSYS 17.2 APDL Multiphysics, where the experimentally observed mass change due to carbonation was incorporated while keeping other parameters constant to examine its influence on the electromechanical response. The carbonation depth of the specimens was also measured to correlate the experimental observations with the deterioration process. The results indicate that the EMI-based monitoring approach is capable of identifying carbonation-induced material degradation and reinforcement corrosion at an early stage. The study highlights the potential of integrating experimental monitoring with numerical analysis for improved durability assessment and maintenance planning of reinforced concrete structures. *→ Session program*

Seasonal variation of natural frequencies of a concrete beam bridge from consumer-grade accelerometers

Christian Petrich, SINTEF Narvik

Abstract. As part of structural health monitoring, operational modal analysis is used to determine mode shapes and frequencies of a structure. It is well established that temperature influences mode frequencies. Here we present the temperature dependence of the transversal movement recorded at three locations along an 804 m long concrete beam bridge over 18 months. As part of a monitoring program of the expansion gaps, ancillary vibration measurements were performed with consumer-grade tri-axial MEMS accelerometers. Mode frequencies were determined by two methods: COV-SSI of the three components and tracking of frequency peaks of a sequence of power spectral densities (PSD). Both methods yielded the same conclusions in this investigation. Frequencies were related to a temperature measurement performed 5 cm inside the beam. Temperatures ranged from –10 °C to 20 °C. It was found that the frequency increased linear with decreasing temperature below approximately 5 °C at a rate of approximately 0.0035 Hz/°C for the lowest modes. At higher temperatures, frequencies tended to be significantly above the low-temperature trend line especially during periods of generally increasing temperatures. Depending on the measurement location, those higher frequencies appeared to be either independent of temperature or increasing with increasing temperature. The observed range of mode frequencies was 0.09 Hz in the first two modes. It is concluded that simple numerical models of the structural behavior of the bridge should be most readily comparable with measurements performed in winter. *→ Session program*

LONG-TERM STATIC AND DYNAMIC STRUCTURAL HEALTH MONITORING OF A CABLE-STAYED BRIDGE

Simone Quarchioni, Università Politecnica delle Marche

Abstract. Bridges play a primary role in road and railway networks, as their inoperability due to damage or collapse following natural disasters or ageing has a significant impact from both social and economic perspectives. For this reason, continuous and reliable structural health monitoring (SHM) systems are essential, particularly for bridges along strategic routes. This paper presents results of a three-year monitoring campaign of the Filomena Delli Castelli cable-stayed bridge in Central Italy. The SHM system was designed and installed to address multiple tasks, such as static, dynamic, seismic and exceptional events monitoring. The monitoring layout includes accelerometers, velocimeters, load cells, displacement transducers, thermocouples, and a weather station, enabling the acquisition of both structural and environmental data that influence the bridge's behaviour. Modal parameters are continuous identified through an automated modal tracking procedure and several data normalization strategies are investigated to mitigate the influence of environmental and operational variability on both static and dynamic measurements. The normalized features are subsequently analysed using control charts to develop a comprehensive SHM framework for the bridge. Results demonstrate the effectiveness of the proposed methodology for long-term bridge monitoring using a limited but effective sensor network.
→ *Session program*

Direct and indirect Structural Health Monitoring of steel railway bridges: A state-of-the-art preview and research gaps

Rune Schlanbusch, NORCE

Abstract. Structural Health Monitoring (SHM) of steel railway bridges is essential to ensure safety, serviceability, and long-term asset management, especially under increasing traffic loads and aging infrastructure. This motivates the development of SHM solutions that are reliable, cost-effective, and scalable for large bridge networks. The predominant monitoring strategy is direct SHM, in which structural responses (strain, accelerations, displacements) are measured via sensors placed on the bridge and analysed using machine learning methods equipped with data-based models. The direct approach offers high fidelity and interpretability but often entails high installation and maintenance costs, complex instrumentation, and limited scalability. A more recent strategy is indirect SHM, which deduces the bridge condition from responses measured via sensors placed on passing trains, again using machine learning methods coupled with data-based models. The indirect approach is motivated by the desire to monitor many bridges using instrumented trains, thus offering improved scalability and lowering the monitoring costs per bridge. However, it faces challenges such as the sensitivity to train–track–bridge interaction, the environmental and operational variability, and the need for robust domain adaptation and generalization. Despite the growing interest, important research gaps remain including the existence of only one comparative study between direct and indirect SHM in railway bridges existing, the existence of only two review papers specifically addressing direct SHM in railway bridges, and the very few studies focusing on indirect SHM in steel railway bridges. The main goal of this article is to review the state-of-the-art of the direct and indirect SHM methods applied to steel railway bridges and to highlight the principal research gaps, thereby providing guidance for future methodological developments and practical implementations. This is joint work with Mehrisadat Makki Almadari (University of New South Wales), Zihao Liu (University of New South Wales), Christos Sakaris (NORCE). → *Session program*

Data processing and damage assessment in the italian Seismic observatory of structures

Daniele Spina, Department of Civil Protection - Italy

Abstract. The Seismic Observatory of Structures is described. It is a network comprising more than 170 civil engineering structures, including buildings, bridges and dams, equipped with a permanent system for accelerometric measurement of seismic response. The network was established in the late 1990s and is managed directly by the Italian Civil Protection Department. In addition to the criteria used to design the sensor layout for the various structural typology and the network's operating procedures during a seismic event, particular attention will be focused on the methods used to process experimental data

and to assess and represent the level of damage sustained by structures affected by the earthquake.
→ *Session program*

Operational Modal Analysis of the Bell Tower of Messina: Investigating Environmental Effects on Natural Frequencies and Mode Shapes

Daniele Storni, UiT The Arctic University of Norway

Abstract. Operational Modal Analysis (OMA) enables the identification of structural dynamic properties from output-only measurements under ambient excitation. However, environmental and operational variability, such as temperature fluctuations, can significantly affect the estimated modal parameters, complicating the interpretation of structural health monitoring data. This paper investigates the influence of environmental factors on both the natural frequencies and, notably, the mode shapes of a historic structure. Utilizing long-term monitoring data from the Bell Tower of the Cathedral of Messina as a case study, an OMA framework is applied to track the evolution of modal parameters over time. The results successfully highlight the strict dependence of the structural dynamic response on environmental variables, demonstrating that temperature effects are not limited to frequency shifts but also noticeably alter the modal vectors. The study contributes to a deeper understanding of environmental impacts on complex masonry structures, providing crucial insights for reliable long-term structural health monitoring and damage detection strategies.
→ *Session program*

Session on Technologies for Sustainable Urbanization in the Arctic: Environmental Engineering

Session chairs: Mohamad Mustafa and Raj Calay → *Full program*

Session program

Monday	14:40-15:10	**Dang**
	15:15-15:45	**Thakur**
	15:50-16:20	**Khader**
Wednesday	10:20-11:10	**Ejigu**
	11:10-11:40	**Asokan**
	11:40-12:10	**Mishra**

Chemiluminometer for Heavy metal detection in Drinking water samples

Reshma Pindiyathpady Asokan, BITS Pilani Hyderabad Campus

Abstract. Heavy metal contamination of water resources has emerged as a critical environmental and public health concern due to the persistence, toxicity, and bioaccumulation potential of metals such as lead (Pb^{2+}), mercury (Hg^{2+}), cadmium (Cd^{2+}), and chromium (Cr^{6+}). These contaminants can enter aquatic systems through industrial discharge, mining activities, agricultural runoff, and corrosion of infrastructure, posing significant risks even at trace concentrations. Conventional analytical methods for heavy metal detection, including spectroscopic and chromatographic techniques, provide high accuracy but often require complex instrumentation, trained personnel, and laboratory-based analysis, making them less suitable for rapid on-site monitoring. Chemiluminescence (CL) sensing has emerged as a promising alternative due to its high sensitivity, minimal background interference, and ability to operate without external excitation sources. In this study, a chemiluminescence-based detection strategy for monitoring hazardous heavy metals in water is presented. The sensing principle relies on the modulation of the luminol-hydrogen peroxide chemiluminescent reaction, where specific metal ions influence the generation of reactive oxygen species, resulting in measurable variations in light emission intensity. By incorporating selective recognition elements and signal-enhancing nanomaterials, the platform enables improved sensitivity and potential differentiation of multiple metal ions through distinct luminescence response patterns and reaction kinetics. The emitted signals are captured using compact imaging device (i.e., a smartphone), enabling quantitative analysis through digital intensity extraction and temporal profiling. The proposed approach offers advantages such as rapid response, low reagent consumption, and compatibility with portable sensing platforms. This chemiluminescence-based framework provides a pathway toward developing scalable and field-deployable systems for water quality monitoring, facilitating timely detection of toxic heavy metals and contributing to improved environmental surveillance and public health protection. → *Session program*

Microbial fuel cell as secondary wastewater treatment

Nga Dang, SINTEF Narvik

Abstract. Microbial fuel cell (MFC) is a green and innovative technology with several advantages: i) it can treat wastewater while simultaneously producing electricity; ii) it uses only about one-tenth of the energy required by activated sludge aerobic system; iii) it produces less sludge and offer the possibility of directly recovering nutrients. Our ambition in this work is to test MFC as a secondary treatment that can be integrated into existing treatment facilities in sparsely populated areas along the Norwegian coast to improve the quality of the discharge water. For that reason, the water discharges from municipal and fish processing treatment facilities were treated in both air-cathode (AC-MFC) and two-chamber MFCs (2C-MFC) as secondary treatment, in lab scale. COD removals were higher than 70% for both systems. Nitrogen removals were 20 and 70% for AC-MFC and 2C-MFC respectively. Higher energy recovery was obtained from the 2C-MFC. No inhibition of MFC operation, due to toxic substances in the wastewaters was observed. → *Session program*

Health risk assessment and management framework for Different Water Systems—One Health approach

Fasil E Ejigu, UiT The Arctic University of Norway

Abstract. This study introduces a structured health risk assessment and management framework for various water systems, including recreational waters, on-site greywater systems, and water reuse in food production. Using studies that combine hydrodynamic modelling with quantitative microbial risk assessment (QMRA) for bathing waters, greywater treatment and disposal in stratified infiltration media, and treated greywater reuse in hydroponic systems, it shows how pathogen and contaminant fate and transport can be measured under realistic loading and exposure scenarios. The framework covers hazard identification, exposure assessment, dose–response analysis, and risk characterisation for key reference pathogens and specific chemicals and connects these to management measures such as multiple-barrier treatment, optimised filter configurations, setback distances, event-based advisories, and safe operational practices. Emphasising uncertainty and sensitivity analyses helps identify main risk drivers and prioritise interventions, with examples illustrating how treatment effectiveness, rainfall events, water ingestion, and pathogen infectivity influence health-based targets. The presentation ends by demonstrating how such an integrated framework can support evidence-based design and operation of both decentralised and centralised water systems, and guide policy and water safety planning to protect public health across a range of water resource uses. *→ Session program*

Modelling of Windbreaks in Large-Domain Computational Fluid Dynamics Simulations

Erlend Entner, UiT The Arctic University of Norway, Faculty of Engineering Science & Technology – Department of Buidling, Energy & Material Science

Abstract. This study presents a methodology for modelling the wind shield effects of a windbreak, or porous fence, within a computational fluid dynamics simulation. The work constitutes a contribution to wind engineering, in which protection against high winds and adverse weather conditions is achieved through the implementation of windbreak structures. Some models of windbreak are reviewed. These models contain empirical constants that must be determined prior to application in large-domain simulations. The method proposed in this paper eliminates the need for full-scale or laboratory experiments, relying exclusively on computational fluid dynamics simulation to determine the required model constants. A large-domain simulation incorporating a windbreak is subsequently performed using constants estimated from dedicated computational fluid dynamics simulation analyses. The results are validated against full-scale experimental measurements conducted at the Hokkaido University campus.
→ Session program

Exploring Biofilm-Electrode Interactions in Microbial Electrochemical Systems for Sustainable Hydrogen Production

Safa Khader, Birla Institute of Technology & Sciences (BITS-Pilani) Hyderabad Campus.

Abstract. The development of sustainable hydrogen production technologies is essential for the transition toward carbon-neutral energy-systems. Microbial electrolysis cells (MECs) offer a promising approach, though their efficiency remains limited by slow electron transfer, unstable biofilms, and energy losses. This work aims to investigate the formation and characterization of electroactive microbial biofilms on conductive electrodes to improve hydrogen generation in MECs. The study will focus on optimizing biofilm-electrode interactions and enhancing electron transfer behavior in MEC configurations, while addressing challenges such as stability, methanogenesis losses, and internal resistance. This work will explore MEC or related biofilm-based systems, focusing on reactor operation, electrochemical analysis, wastewater treatment, and hydrogen evolution from synthetic or real wastewaters. Electroactive microbial biofilms will be cultivated on conductive electrodes to develop efficient bioelectrodes. Electrochemical techniques, such as cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS), will be employed to evaluate electron transfer efficiency and biofilm activity. Hydrogen production performance will be assessed by monitoring current generation and cathodic catalytic activity during system operation. The study will provide insights into the relationship between biofilm properties and hydrogen evolution efficiency. These findings will contribute to improved bioelectrode design

and the advancement of microbial electrochemical systems for sustainable hydrogen production and wastewater treatment.

→ *Session program*

Multi-Temporal Detection of Paleochannels and Hydrological Reconstruction of the Assi River Using NDVI, Landsat Imagery, and DEM-Based Analysis

Anurag Mishra, UiT The Arctic University of Norway, Narvik

Abstract. Paleochannels, or abandoned river courses, provide valuable information about past fluvial dynamics, groundwater recharge potential, and landscape evolution. Identifying these ancient channels is particularly important in densely populated regions where historical river systems have been altered due to urbanisation and land-use change. This study investigates the paleochannels of the Assi River, a tributary of the Ganga River in the Varanasi region of northern India, using a multi-temporal remote sensing and GIS-based approach. A total of 318 Landsat-5 Thematic Mapper (TM) images from 1984 to 2012 with cloud cover below 10% were analysed using Google Earth Engine. A Seasonal Normalised Difference Vegetation Index (S-NDVI) was developed to capture vegetation dynamics associated with groundwater table fluctuations during pre-monsoon, monsoon, and post-monsoon periods. Additional analytical techniques including Principal Component Analysis (PCA), Tasselled Cap Transformation (TCT), and Grey Level Co-occurrence Matrix (GLCM) texture analysis were applied to enhance the detection of buried fluvial features. Digital Elevation Model (DEM) analysis using SRTM data was conducted to validate the geomorphological characteristics of the identified paleochannels. A DEM burning approach was applied along the delineated paleochannel network to simulate ancient drainage pathways, followed by hydrological modelling for catchment delineation and flow accumulation analysis. The results indicate that the paleochannel of the Assi River has an estimated width of 200–300 m, significantly wider than the present channel. Groundwater table data from 2011–2020 show relatively higher groundwater levels along the identified paleochannel zones, suggesting their continued influence on subsurface hydrology. The integrated approach demonstrates the effectiveness of combining multi-temporal satellite data with hydrological modelling for paleochannel detection and provides valuable insights for groundwater management and river restoration in the Ganga basin.

→ *Session program*

Session on Technologies for Sustainable Urbanization in the Arctic: Fuel Cells

Session chairs: Mohamad Mustafa and Raj Calay *→ Full program*

Session program

Monday	10:30-11:20	**Borissova**
	11:20-11:50	**Azhar**
	11:50-12:20	**Al-Hamdan**

Thermodynamic Modelling, Component Matching for Optimal Control of a Hybrid Fuel Cell–Turbofan Aircraft Propulsion System

Qusai Z. Al-Hamdan, UHI Perth, University of the Highlands and Islands, Scotland

Abstract. The aviation sector is facing increasing pressure to reduce greenhouse gas emissions and improve propulsion efficiency while maintaining the operational reliability and performance demanded by modern aircraft systems. Hybrid propulsion architectures integrating hydrogen fuel cells with turbofan gas turbine engines have emerged as a promising pathway toward sustainable aviation. However, the integration of multiple propulsion and power-generation subsystems introduces significant challenges in thermodynamic modelling, component matching, transient performance prediction, and real-time optimal control across varying flight conditions.

This paper presents the modelling, simulation, and optimal control of the gas turbine engine part of the combined fuel cell–turbofan hybrid propulsion system for aviation applications. Building upon established gas turbine engine modelling methodologies, the work extends conventional aerothermodynamic simulation approaches traditionally applied to gas turbine performance analysis toward the integration of hybrid-electric aircraft propulsion systems. The proposed methodology considers the turbofan engine as a complex assembly of aerothermodynamically coupled components whose design-point and off-design performance characteristics significantly influence the overall hybrid system behaviour.

A comprehensive thermodynamic simulation framework is developed to model the dynamic interaction between the turbofan engine, fuel cell stack, electrical power conversion system, and energy management network. This part of the study incorporates compressor and turbine component matching techniques through the superimposition of transformed performance characteristic maps to establish equilibrium operating conditions and stable running lines throughout the flight envelope. The modelling framework enables the prediction of transient engine behaviour, operating envelopes, component efficiencies, surge margin proximity, and allowable turbine inlet temperature limits under varying flight and loading conditions.

To address the operational complexity of the hybrid propulsion architecture, an optimal supervisory control strategy is proposed for coordinated thrust and power management between the fuel cell and turbofan subsystems. The controller dynamically allocates power demand to minimise fuel consumption and improve propulsion efficiency while satisfying thrust requirements, maintaining component operational constraints, and preserving fuel cell health limitations. Lower-level control loops regulate spool dynamics, fuel flow, electrical power distribution, and fuel cell operating conditions to ensure stable system response during transient manoeuvres including take-off, climb, cruise, and rapid throttle changes.

Simulation results demonstrate that the integrated thermodynamic modelling, component mapping, and optimal control methodology provides effective prediction and management of hybrid propulsion system behaviour under both design and off-design operating conditions. The proposed approach offers improved transient response characteristics, enhanced operational stability, and more efficient hybrid power utilisation across the flight mission profile. The study highlights the importance of advanced gas turbine performance simulation and component matching methodologies as foundational tools for the development of next-generation hybrid fuel cell–turbofan propulsion systems for sustainable aviation applications. *→ Session program*

Temperature Gradient and Hotspot Formation in Planar SOFC under Varying Fuel Utilization Ratios

M. Uzair Azhar, The Arctic University of Norway

Abstract. The efficiency and durability of planar solid oxide fuel cells (SOFCs) are strongly influenced by thermal management. Localized hotspots and non-uniform temperature distributions, resulting from uneven electrochemical reactions and fuel utilization, can significantly accelerate material degradation, limit cell performance, and reduce operational lifetime. Understanding the relationship between fuel utilization and thermal behavior is therefore critical for the design of reliable high-temperature fuel cell systems. In this study, a two-dimensional model of a planar SOFC was developed using ANSYS Fluent. The model incorporates species transport, Butler–Volmer reaction kinetics, and temperature-dependent material properties, enabling a coupled simulation of electrochemical reactions and heat generation within the fuel cell. Various fuel utilization ratios were considered in a parametric analysis to examine their effect on temperature gradients, hotspot formation, and current density distribution. The approach provides a framework to identify operational strategies that minimize thermal stress and improve uniformity of reaction rates across the cell. The insights gained from this modeling effort are intended to support improved thermal management, enhance cell reliability, and inform the design and operation of planar SOFC systems for high-efficiency energy conversion. This work demonstrates the importance of integrating electrochemical and thermal modeling in the development of robust fuel cell technologies.
→ *Session program*

Alternative Vehicles and CO_2 Emissions: The Importance of Energy-System Context

Ana Vassileva Borissova, Nord University

Abstract. The transition towards low-carbon transport is often discussed through comparisons between battery-electric vehicles, hybrid vehicles and hydrogen-based transport solutions. However, the environmental performance of these technologies depends strongly on the characteristics of the energy systems in which they operate. This study examines the influence of national electricity-generation systems on life-cycle CO_2 emissions from alternative vehicle technologies. Comparative analyses based on case studies from Europe and Latin America, representing diverse energy profiles, were used to evaluate how regional energy-system characteristics affect overall environmental performance.

The results demonstrate that the same vehicle technology can exhibit very different CO_2 emissions in different countries due to variations in national energy systems. The analyses further illustrate how vehicle range, battery production and electricity-generation characteristics influence life-cycle emissions across European and Latin American energy systems.

The findings highlight that no single transport technology performs best under all conditions. Instead, technology assessment should be conducted within the broader context of regional energy systems, infrastructure characteristics and long-term decarbonisation pathways.

The study demonstrates the importance of system-level thinking when evaluating future transport strategies and provides insights relevant to both engineering design and energy-policy decision-making.
→ *Session program*

Session on Technologies for Sustainable Urbanization in the Arctic: Materials and Modelling

Session chairs: Mohamad Mustafa and Raj Calay *→ Full program*

Session program

Thursday	10:20-11:10	**Madaan**
	11:10-11:40	**Yashwant**
	11:40-12:10	**Kapoor**
	14:40-15:10	**Entner**
	15:20-15:50	**Malila**
Friday	10:20-11:10	**Das**
	11:10-11:40	**Thanh**
	11:40-12:10	**Taj**

Undetected, Unregulated, Unsafe: The Reality of Emerging Contaminants in our water

Sovik Das, Indian Institute of Technology Delhi

Abstract. Emerging contaminants (ECs) such as pharmaceuticals, endocrine-disrupting compounds, microplastics, per- and polyfluoroalkyl substances (PFAS), and plastic additives are increasingly detected in aquatic environments, raising serious concerns due to their persistence, bioaccumulation potential, and limited regulatory oversight. Conventional wastewater treatment processes are largely ineffective for their complete removal, enabling their continuous release into natural water bodies and posing ecological and human health risks.

Recent investigations have explored electrochemical and bioelectrochemical technologies as promising approaches for the detection, degradation, and mitigation of ECs in water and wastewater systems. Electrochemical advanced oxidation processes, including electro-oxidation and electro-Fenton systems, demonstrate significant potential for degrading endocrine disruptors, parabens, phthalates, and pharmaceutical compounds through the generation of highly reactive oxidative species. Removal efficiencies exceeding 80–90% have been achieved under optimized operating conditions, accompanied by substantial reductions in total organic carbon and toxicity of degradation intermediates. In addition, electrochemical impedance spectroscopy has been proposed as a rapid and cost-effective approach for microplastic quantification in aqueous matrices, offering comparable accuracy with significantly reduced analytical cost and time. Integrated bioelectrochemical platforms further enable enhanced contaminant removal while supporting resource recovery pathways such as biohydrogen generation. Collectively, these advances highlight the potential of electrochemical technologies to address the complex challenge of emerging contaminants and support the development of sustainable and circular water treatment systems. *→ Session program*

Impact of using coarse and fine recycled concrete aggregates on durability and environmental performance of geopolymer concrete

Kanish Kapoor, Dr B R Ambedkar National Institute of Technology Jalndhar

Abstract. The incorporation of Recycled Concrete Aggregates (RCA) in Geopolymer concrete offers a sustainable solution for reducing construction and demolition waste while conserving natural resources. This study investigates the effect of using coarse and fine recycled concrete aggregates on the durability and environmental performance of geopolymer concrete. Geopolymer mixes were prepared with varying replacement levels of natural aggregates by recycled coarse and fine aggregates, and their durability was evaluated through water absorption, sorptivity, resistance to chloride ingress, sulphate attack, and acid exposure. The results indicate that although the inclusion of recycled aggregates increases porosity-particularly in mixes containing fine recycled aggregates, the geopolymer binder matrix effectively mitigates adverse durability effects due to its dense alumino-silicate structure. Optimum performance was observed at moderate replacement levels, maintaining durability within acceptable limits.

→ *Session program*

Measuring Supply Chain Resilience for Sustainability

Jitender Madaan, Indian Institute of Technology Delhi

Abstract. Developing Resilience has now been seen as current focus for researchers and practitioners in design and development of supply chain networks. Here Resilience demonstrates the ability of current networks to withstand and overcome disruption caused by natural or manmade hazards. Under these hazard supply chain networks are subject to various risks, disturbances and disruptions which disrupt flows as intended. Such network challenges are often addressed by traditional risk management, whose focus is on risk prevention from characterizing the uncertainty of risk events to evaluating the impact. These risk-oriented practices are considered inadequate, even if widely recognized, due to the nature of certain risks – high inevitability and consequences in post Covid-19 pandemic impacts on supply chains. Furthermore, when it came to disruptions with a low likelihood of occurrence and substantial impact on performance of overall supply chains. Currently, supply chain industry specially when covering circularity began to explore level of resilience in network – approach enhance the capability of supply chains to withstand disruptions due to unavailability of manpower and hygiene. Here vital research questions to explore reason for resilience, composition of resilience, and measure resilience. To enrich existing literature, this research talks focuses on the measurement of resilience of supply chain and its link with flexibility/agility in improving performance –as an alternative to exploit chaos due to disruptions. This study will critically focus on resilient product delivery along with recovery network that will allow enterprises and stakeholders to achieve intended sustainability goals. The novelty of this paper also lies in evaluating current supply chain networks and improvement in network with closing the loop from the resilience perspective. Proposed, resilience metrics can be used to evaluate the existing supply chain system and the response before, during, and after disruptions have occurred. → *Session program*

FsyNet Project: co-development of physics education in Finnish universities

Jussi Malila, Oulu University

Abstract. TBA → *Session program*

Phase Change Materials for Thermal Energy Management in Cold Climates: A Review of Applications and Performance

Samad Ali Taj, UiT The Arctic University of Norway, Narvik

Abstract. Phase change materials (PCMs) have demonstrated significant potential in controlling energy demand and enhancing thermal management systems through their thermal energy storage (TES) capability. While plenty of literature exists on PCM applications in hot and cold temperate climates, their utilization and suitability in Nordic and similar cold climate regions remain comparatively underexplored. Cold climates present distinct challenges, including prolonged sub-zero ambient temperatures, extended heating seasons, and reduced solar availability during winter seasons, which necessitate supplementary thermal management strategies. This article fills this gap by investigating the applicability of PCMs in subzero cold climate regions with a particular focus on low melting temperature PCMs. A detailed analysis is provided on their thermophysical properties, phase transition behavior, and suitability for heating applications. The review examines the integration of PCMs in building envelopes and domestic water heating systems to enhance heat storage capacity, stabilize indoor thermal conditions, and reduce peak heating demand. Moreover, the article highlights emerging applications of PCMs as thermal buffers in the transportation sector, leveraging cold start in internal combustion engines, battery temperature management for electric vehicles and as an icing-mitigation agent in sub-zero temperatures. The findings evaluate the performance of PCMs to improve energy efficiency and provide better thermal resilience in cold climate regions. → *Session program*

Valorisation of Algal biochar in heterogeneous bio-electro fenton process for the degradation of Ofloxacin in wastewater

Somil Thakur, UiT The Arctic University of Norway

Abstract. Ofloxacin (OFL) is a broad-spectrum fluoroquinolone antibiotic used to treat bacterial infections such as stomach related ailments. However, when discharged to environment, affects aquatic biodiversity and has impact on the growth of the non-target microorganisms. This result in changing the micro-environment and has harmful effects on aquatic ecosystems. Even at present in microquantity it can alter the property of safe usable water. For this reason, OFL is also often termed as Emerging Contaminant (EC). This work investigated green sustainable methods such as algal biomass and biochar to remove this contaminant from wastewater. The results shows that the method is versatile and effective for a wide array of pollutants. This is joint work with Sundipan Bhomwick (IIT Kharagpur).
→ Session program

Modelling the Effect of Biomass Moisture Content and Feed Rate on the Efficiency of a Biomass-Based Water Heating System

Hung Nguyen Thanh, UiT The Arctic University of Norway – Fak. IVT, Institutt Bygg-Energi-Material Teknologi

Abstract. Biomass-fired water heating systems are widely used for sustainable heat production, but their performance is strongly influenced by the moisture content of the biomass fuel. This study investigates the effect of biomass moisture content and biomass feed rate on the overall efficiency of a biomass-based water heating system consisting of a combustion chamber and a shell-and-tube heat exchanger. Pine biomass is considered as the representative fuel. A thermodynamic analysis was performed to evaluate system performance. In the simulation, the excess air ratio was maintained at 10%, while the heating demand was kept constant, corresponding to a water mass flow rate of 60 kg/s heated from 20 °C to 80 °C. The results show that increasing biomass moisture content reduces the effective energy available from combustion due to the energy required for water evaporation, thereby decreasing system efficiency. The calculated efficiency ranges from approximately 34% to 75%, depending on biomass moisture content and feed rate. Higher moisture levels require increased biomass feed rates to maintain the same heating demand, leading to higher fuel consumption. These results highlight the importance of controlling both biomass moisture content and biomass feed rate to improve system efficiency. *→ Session program*

Molecularly Imprinted Quartz Crystal Microbalance Sensor for Detecting Acetylcholine Neurotransmitter

Yashwant, Indian Institute of Technology Delhi

Abstract. Acetylcholine (ACh) is a crucial neurotransmitter associated with learning and memory, and its levels decline in patients with Alzheimer's disease (AD). A molecularly imprinted polymer (MIP) was created using 3-aminopropyltrimethoxysilane (APTMS) as a functional monomer through a sol-gel process to detect ACh. The polymer network of APTMS and silica, along with the pores of ACh on the Quartz crystal microbalance (QCM) crystal surface, was used to adsorb ACh dissolved in a 1X PBS buffer across a concentration range of 10−10 M to 10−6 M at three different flow rates: 25 μL/min, 50 μL/min, and 75 μL/min. The ACh-imprinted MIP on silica surfaces was characterized using FTIR, contact angle measurements, and QCM to evaluate hydrophilicity, functional groups, and adsorption properties. The equilibrium mass of ACh adsorbed on the MIP over the QCM crystal surface was highest at a flow rate of 25 μL/min, followed by 75 μL/min, and then 50 μL/min. The best reusability ratio for ACh adsorption at a concentration of 10−10 M on the MIP over the QCM surface was observed during the second run at 75 μL/min. The imprinted factor was measured at 2.71 for a flow rate of 25 μL/min with ACh at 10−10 M. The MIP demonstrated the highest specificity for ACh, followed by a mixture of ACh and GABA, and then GABA alone, both at 10−10 M. The selectivity factors showed that the MIP has a greater affinity for ACh in mixture with GABA and for GABA solutions, especially at the lower flow rate of 25 μL/min. *→ Session program*

Poster session

Wednesday 13:30-15:00

- To maximize their exposure, the posters will be setup at lunch time on Monday. Late arrivals should please contact the organizers for help.
- Participants must bring their printed posters. The conference cannot handle the printing process.
- The conference will provide Blu Tack to affix the posters, so heavy materials should be avoided.

Dynamic Response of Immune Feedback Control Analogy in Power System Applications

Isaac Kweku Aidoo, UiT The Arctic University of Norway

Abstract. This paper presents an immune-inspired feedback control approach for power system applications with emphasis on dynamic stability enhancement and adaptive response under nonlinear operating conditions. The proposed method is motivated by the biological immune system, which possesses the ability to detect disturbances, coordinate protective responses, and maintain homeostasis in the presence of external threats. By drawing an analogy between biological homeostasis and power system stability, the study develops an adaptive control framework capable of regulating system behavior under varying operating conditions. Modern power systems are increasingly challenged by uncertainties arising from renewable energy integration, load variations, and network disturbances, making conventional control methods less effective in highly dynamic environments. The proposed immune-inspired controller mimics the self-regulating and disturbance-mitigation characteristics of the immune response to improve system resilience and operational stability. In this framework, disturbances within the power network are treated similarly to foreign agents in biological systems, while the controller continuously adapts its response to preserve system equilibrium. Simulation results obtained from a discrete-time single-input single-output nonlinear system demonstrate the feasibility and effectiveness of the proposed approach. The controller exhibits satisfactory dynamic response characteristics, improved disturbance rejection capability, and robust adaptive stabilization performance under different operating conditions. The findings highlight the potential of immune-inspired control strategies as a biologically motivated and intelligent solution for enhancing stability and resilience in future smart power systems.
→ *Full program*

Emerging Materials, Advanced Surface Engineering, and Sustainable Manufacturing Pathways for High-Performance Bipolar Plates in PEM Fuel Cells

Farqad Al-Hadeethi, University of Uskudar

Abstract. Hydrogen-based energy systems have attracted considerable scientific and industrial interest as viable alternatives to conventional fossil-fuel technologies. Within this context, proton exchange membrane fuel cells (PEMFCs) have emerged as highly efficient electrochemical devices due to their high power density, rapid start-up capability, and environmentally benign operation. Despite these advantages, the widespread commercialization of PEMFC systems remains strongly dependent on the development of durable and economically feasible bipolar plates capable of operating under harsh electrochemical environments.

This work provides a critical and detailed investigation of recent advances in bipolar plate technologies with emphasis on material development, surface modification strategies, and modern manufacturing methodologies. The study evaluates the performance of conventional graphite and metallic bipolar plates alongside newly polymeric and carbon-based composite materials. Particular attention is devoted to the role of nanostructured conductive additives, including graphene derivatives, carbon nanotubes, expanded graphite, and hybrid reinforcement systems, in enhancing electrical conductivity, mechanical stability, thermal transport, and corrosion resistance.

Moreover, advanced surface engineering techniques designed to minimize interfacial degradation and improve long-term operational stability are comprehensively discussed. Various protective coating systems, such as diamond-like carbon coatings, nitrides, carbides, and multilayer thin films, are examined in relation to electrochemical durability and conductivity retention under PEMFC operating conditions. The influence of manufacturing technologies, including compression molding, injection molding,

additive manufacturing, and emerging high-throughput fabrication approaches, is also analyzed with respect to production scalability, geometric precision, and cost reduction.

The present work further highlights the key scientific challenges restricting industrial implementation, particularly issues associated with coating adhesion, conductive filler dispersion, interfacial contact resistance, and long-term material degradation. Finally, future research opportunities involving multifunctional nanocomposites, intelligent coating architectures, and digitally assisted manufacturing technologies are proposed as promising pathways toward the realization of lightweight, highly conductive, and corrosion-resistant bipolar plates for next-generation PEMFC applications. *→ Full program*

Mathematical model of a stock market

Dila Bhandari, Tribhuvan University

Abstract. The paper develops a mathematical model of the stock market based on a broad class of stochastic processes to describe the evolution of risky asset prices. The model is formulated on a properly constructed probability space, where asset prices are represented by random processes with jumps, allowing for both finite and infinite jump activity. A new concept of non-singular martingale is introduced, and an integral representation theorem for a wide class of local martingales is established. This result provides the foundation for defining an effective stock market. Within this framework, a mathematical theory of European-type option pricing is constructed, leading to new pricing formulas and explicit characterizations of the investor's capital process and self-financing strategies corresponding to minimal hedging.
→ Full program

Design and Installation of a Long-Term Monitoring Station for Concrete Durability in Arctic Marine Conditions

Rekik Derso, UiT The Arctic University of Norway

Abstract. Concrete structures in Arctic environments experience complex durability challenges caused by the combined effects of freeze-thaw action, tidal variations, and chloride ingress. Since laboratory-based durability tests do not fully represent these field conditions, long-term field monitoring under natural Arctic exposure is important for understanding concrete durability. The monitoring station provides a long-term in-situ data linking environmental exposure and internal material behavior in Arctic conditions. This paper presents the design and implementation of an instrumented monitoring station developed to investigate the long-term durability performance of low carbon concrete under Arctic conditions at Narvik Harbour in northern Norway. The station integrates instrumented and non-instrumented concrete samples exposed in atmospheric, tidal, and submerged zones. Embedded multi-parameter sensors enable continuous monitoring of temperature, electrical resistivity, chloride-related parameters, and corrosion indicators. The monitoring station was established following a systematic site selection process within the harbour. Several installation alternatives were evaluated considering exposure representativeness, structural feasibility, operational safety, and long-term accessibility. The final installation location was selected in the Nordkaia area of the harbour which provides representative exposure conditions while minimizing interference with harbour operations. Large concrete samples incorporating both a reference mix and supplementary cementitious material mixes were cast and cured prior to the installation. The concrete samples were designed to be exposed in three exposure zones – atmospheric, tidal and submerged. To enable continuous monitoring, the concrete samples were instrumented with embedded multi-parameter sensors capable of measuring temperature, chloride concentration, pH, concrete resistance, steel potential and corrosion current. The sensors were installed within the concrete at multiple depths. The sensors were connected to integrated data loggers through cables before field installation. The concrete samples were mounted in a steel frame structure designed to ensure exposure and allow safe routing and protection of the sensor cables. The monitoring station provides a unique experimental platform for studying freeze–thaw durability under Arctic conditions. By combining environmental monitoring with embedded multi-sensor technology, the system enables long-term observation of degradation processes and provides valuable data for evaluating the durability performance of sustainable low-carbon concrete. *→ Full program*

From Ship to Science: Unlocking the Potential of Panoramic Cameras in Polar Research

Martha Finke, UiT The Arctic University of Norway

Abstract. Originally designed for tourism applications, such as on cruise ships and in ski resorts, 360° panoramic camera systems are increasingly being utilized in polar research to enhance public outreach and scientific exploration. During the MOSAiC expedition (2019–2020), the RV Polarstern was equipped with a 360° panoramic camera, capturing high-resolution images every 20 minutes over a full annual cycle of Arctic sea ice. This innovative approach bridges the gap between localized high-resolution measurements and broad-scale satellite observations, providing a unique perspective on the heterogeneity of sea ice, melt ponds, and ice-air interactions—features often missed by traditional orbital sensors.

To maximize the scientific utility of these images, we georeferenced and orthorectified the panoramic data, transforming ship-based observations into analysis-ready spatial datasets. This talk will highlight the potential applications of this dataset, including monitoring ice dynamics, cloud behavior, open water fractions, and integrating radar and weather data. By repurposing technology originally intended for tourism, we demonstrate how panoramic imaging can play a transformative role in advancing cryospheric research and understanding Arctic climate processes. → *Full program*

Critical Risks Measurement in AI-enabled Packaging Supply Chain System

Gulshan Kumar Gaur, Indian Institute of Technology Delhi

Abstract. Emerging economies are facing colossal pressure to meet the consumer expectations along with seamless adoption of sustainable development goals due to technological advancement & market competition. The packaging enterprises in the initiation phase need to consider various aspects of packaging while shifting towards a secure, effective and sustainable solution. AI implementation in the packaging supply chain system (PSCS) has been recognized as a game-changer in driving revenue and growth. AI-based PSCS can effectively address packaging waste and carbon footprint issues while necessitating a holistic and informed decision-support model. This study put an effort into promoting the proactive application of AI-supported PSCS to measure critical risk in facilitating a safe, secure, efficient, effective and flexible infrastructure. The critical risks are identified from the recent literature, verified by professionals and prioritized using the MCDM methods. This framework may also help manage the huge volume and variety of packaging waste in a better way. AI-facilitated PSCS have the potential advantage of reducing the inherent risk issues associated with the PSCS, and packaging executives should gauge current general AI adoption, prioritize the most impactful use cases, and map the key risks to adopt the technology. → *Full program*

Improving the NEWA Wind Atlas through Observation-Driven Corrections and AI-Enabled Multi-Scale Downscaling

Zahra Lakdawala, Fraunhofer Institute for Wind Energy Systems

Abstract. A reliable assessment of regional wind resources is essential for ensuring a secure and efficient transition to renewable energy systems. This work presents an improved framework for the New European Wind Atlas (NEWA) by integrating observational data from met masts and lidar systems to calibrate and correct mesoscale simulations, particularly those based on the Weather Research and Forecasting (WRF) model.

The approach further focuses on advancing multi-scale coupling methodologies that bridge mesoscale atmospheric dynamics with microscale flow representations. Such coupling is critical, as mesoscale models are unable to resolve fine-scale topographic effects, while microscale models lack the ability to capture large-scale wind climatology. Existing approaches face significant limitations in complex terrain due to simplifying assumptions, such as linearized flow models and idealized flow conditions, that are often violated in real-world environments.

To address these challenges, we propose a hybrid framework that incorporates multiple physics representations alongside AI-based downscaling and correction technique. Machine learning models are trained using high-fidelity simulations and observational datasets to improve the representation of complex flows, reduce systematic biases, and enhance spatial resolution across scales.

In addition, this work explores, for the first time within the NEWA context, the impact of climate variability, climate change, and evolving land-surface characteristics on wind resource assessments. Given Europe's diverse and dynamic topographies and land-use patterns, it provides a unique testbed for evaluating these effects within a unified modeling framework.

The resulting methodology aims to deliver a next-generation wind atlas with improved accuracy, robustness, and adaptability thereby supporting better-informed decision-making for wind energy deployment in complex and changing environments.

→ Full program

Spatial Clustering of Kinematic Anomalies for SAE Level 3 Heavy-Duty Transport on the Arctic E6 Corridor

Radosław Łukasik, Posten Bring Bildrift AS, Tromsø, Norway

Abstract. This study presents a spatial decision-support framework for SAE Level 3 automated 25.25 m High-Capacity Transport (HCT) operations in Arctic environments. Using 563,452 telemetry points collected from 93 shuttle missions along the E6 corridor between Tromsø and Narvik, the model identifies spatial patterns of kinematic instability. The framework applies K-Means clustering (k=10) to critical road segments in order to define discrete, georeferenced Take-Over Request (TOR) decision nodes. The proposed methodology enables predictive system deactivation before entering segments associated with elevated maneuvering difficulty, thereby reducing dependence on real-time sensor fusion systems whose performance may deteriorate under subarctic operating conditions.

→ Full program

Investigation of the behavior of railway tracks at low frequencies

Ephraim Nyarko Ebo Otsiwah, UiT The Arctic University of Norway

Abstract. Railways present significant environmental challenges related to noise and vibration, particularly vibrations transmitted through the track into the ground that can affect nearby building foundations and cause annoyance to occupants. These vibrations, which propagate as mechanical waves through the track–ground system, may also lead to structure-borne and re-radiated noise within buildings. While high-frequency railway vibrations have been extensively studied, low-frequency vibrations, typically below 50 Hz remain less well understood despite being most critical for human perception and building response, especially at frequencies below 5 Hz. Railway-induced ground-borne vibration commonly occurs within the 1–100 Hz range and is often the result of overlapping excitation mechanisms, including axle loading, track irregularities, and soil or site resonance. This study investigates the generation and transmission of railway-induced vibrations using a simplified analytical framework in which the rail is modeled as an Euler–Bernoulli beam supported by an elastic half-space foundation. The model is employed to examine vibration trends and to assess the effectiveness of track–ground interaction mechanisms in vibration generation, transmission, and potential mitigation.

→ Full program

Variability of diurnal and nocturnal river water quality in Arctic environments

Penupothula Raju, UiT The Arctic University of Norway

Abstract. Water quality in streams and rivers is not a static phenomenon. Their physical, chemical, and biological parameters tend to fluctuate along their lengths over day and night, which is governed by various atmospheric changes, intensity of solar radiation, and photosynthesis activity. In Arctic river systems, these diurnal and nocturnal variations occur very frequently due to the extreme climatic changes across the seasons; the broader daylight and midnight sun during summers and near-total darkness in winter add complex water quality patterns and ecological changes. Despite having numerous water quality monitoring methods, an index-based tool focusing on the cyclic fluctuations of water quality and various machine learning (ML) techniques identifying the patterns, along with the decision support tool, makes it easier for urban water quality monitoring authorities to fetch water for different purposes for multiple uses with great precision. Rapid urbanisation in the Arctic regions glorifies the importance of monitoring municipal water supply, food security and energy production connected to intelligent prediction tools for better forecasting of the river dynamics. This study looks at how river water quality changes during the day and night in Arctic areas and assesses how well different ML models can predict water quality measurements using a decision-support tool.

→ Full program

Resolving Doppler Ambiguity in Simulated FMCW Radar for High Velocity Targets

Laura-Kristin Scholtz, UiT The Arctic University of Norway

Abstract. Frequency-Modulated Continuous Wave (FMCW) radars are widely used to estimate the range and velocity of moving objects within the radar's field of view. Both range and velocity measurements, however, are subject to unambiguous limits. When the relative velocity between the radar and a target exceeds the maximum measurable Doppler velocity which is determined by the chirp duration (or chirp repetition frequency) and radar wavelength, the resulting Doppler frequency becomes aliased. Consequently, standards range-Doppler processing leads to incorrect velocity estimations. To study this effect, the radar signals are simulated in a controlled environment. In an FMCW radar, the output signal is produced by mixing the transmitted chirp with the received signal which is the delayed and Doppler-shifted echo from the target. A target with a velocity that exceeds the unambiguous Doppler limit is introduced into the simulated receiver signal, enabling a clear analysis of Doppler aliasing under well-defined conditions. The goal of this work is to explore and evaluate signal processing strategies capable of resolving such velocity ambiguities. The resulting framework shall provide a foundation for developing high velocity detection techniques applicable to fast-moving objects, such as space debris.

→ *Full program*

An Intelligent Framework for Damage-Informed Reinforced Concrete Structures Using YOLO26

Sadanand Sinha, Indian Institute of Technology, Kharagpur, West Bengal, India

Abstract. Reinforced concrete (RC) structures form the backbone of modern infrastructure, yet they remain vulnerable to cracking, spalling, and surface deterioration caused by aging, environmental exposure, overloading, and extreme events. Conventional inspection methods rely primarily on manual visual assessment, which is time-consuming, subjective, and difficult to scale for large infrastructure networks. Advances in computer vision and deep learning provide new opportunities to automate and standardize Structural Health Monitoring (SHM) through rapid and reliable damage detection, ultimately enabling more intelligent interpretation of structural condition data.

This paper presents a vision-based intelligent framework for automated damage detection in reinforced concrete surfaces using the YOLO26 deep learning architecture. YOLO26, released by Ultralytics in January 2026, introduces an end-to-end NMS-free detection architecture optimized for real-time performance on edge devices. Within the proposed framework, YOLO26 is used to detect surface defects such as cracks, spalling, and potential reinforcement corrosion, while complementary segmentation models, including U-Net and Mask R-CNN, provide pixel-level characterization of defect geometry.

The models are trained and evaluated on a heterogeneous dataset comprising public benchmarks (SDNET2018, Crack500, NCCD-PF, and Concrete Crack Images) together with field images of RC structural elements. Performance is evaluated using metrics including mean Average Precision (mAP), Dice coefficient, Intersection-over-Union (IoU), precision, and recall, demonstrating reliable detection accuracy suitable for real-time SHM applications.

→ *Full program*

Compound Exposure Screening for Arctic Dam Infrastructure: A Multi-Layer Assessment Using Norwegian Registry and Climate Data

Abu Mohammad Taief, UiT The Arctic University of Norway

Abstract. Norway operates nearly 500 dams above the Arctic Circle. Many of these structures are 50 to 70 years old and face environmental conditions that may differ from those present during their design and construction. Current dam safety management relies on scheduled inspections at fixed intervals, but two dams in the same consequence class can experience very different levels of environmental stress depending on their location, age, and surrounding hazards. This work develops a compound exposure screening framework for Arctic dams, combining multiple data layers to identify structures that warrant closer examination. The framework integrates four layers using existing official data: (1) infrastructure age and design era from the NVE dam registry; (2) climate exposure regimes derived by clustering Arctic weather stations from the Norwegian Centre for Climate Services (Seklima) based on measured temperature records (2015–2024); (3) proximity to NVE-mapped flood zones at 100-year and 200-year return

periods; and (4) monitoring coverage, measured as distance to the nearest meteorological and hydrological stations. Each dam is characterized across all four layers, and compound exposure is assessed where multiple factors converge. Preliminary analysis identifies distinct climate exposure regimes across the study area, with statistically significant differences in infrastructure age between regimes ($p = 0.031$). The compound overlay highlights a subset of dams where aging structures, harsh climate conditions, flood exposure, and limited monitoring coincide. The approach is intended as a practical screening tool to help prioritize where closer engineering examination may be warranted. → *Full program*

High-Sensitivity Quartz-Resonant MEMS Accelerometer System with Hardware-Level GNSS Synchronization for Scalable Structural Health Monitoring

Masayoshi Todorokihara, Seiko Epson Corporation

Abstract. Background. Microtremor measurement and Structural Health Monitoring (SHM) require high-resolution accelerometers and strict time synchronization across distributed networks. Force-Balance Accelerometers (FBA) deliver high metrological performance but constrain dense deployments due to high costs and large form factors. Capacitive Micro-Electromechanical Systems (MEMS) offer scalability but impose a fundamental mathematical trade-off between dynamic range and noise floor, limiting low-frequency stability. Furthermore, conventional analog sensors demand complex Analog-to-Digital Converter (ADC) integration and tedious manual calibration for sensitivity variations, which severely bottlenecks large-scale industrial implementations.

Objective. This study aims to bridge the gap between theoretical vibration analysis and practical engineering deployment by developing a fully digital, high-sensitivity Quartz-resonant MEMS accelerometer system. By integrating the sensor with a custom Global Navigation Satellite System (GNSS) time synchronization board, the primary objective focuses on achieving high-end performance while eliminating ADC dependencies, thereby streamlining field setups and fostering scalable collaborations between academic researchers and industry partners.

Methods. We developed the accelerometer (M-A370) utilizing a Double-Ended Tuning Fork (DETF) quartz resonator paired with a high-density tungsten proof mass to increase the inertial mass fourfold compared to the previous M-A352 model. The transducer design incorporates a 3-channel differential configuration across six elements to mathematically cancel temperature gradients and mechanical stress. For synchronization, we engineered a time synchronization board utilizing an STMicroelectronics 32-bit (STM32) microcontroller hardware timer. This timer captures the GNSS Pulse Per Second (PPS) signal and generates a 1 kHz synchronization pulse strictly through hardware functions, completely eliminating software-induced processing delays. The integrated system, comprising both the sensor and the synchronization board, operates with a total current consumption of around 100 mA at 3.3 V per node.

Results. The tungsten proof mass optimization increased acceleration sensitivity to 550 Hz/g, up from 152 Hz/g in previous single-ended generations (M-A352). The M-A370 demonstrated an ultra-low noise density of 20 ng/$\sqrt{\text{Hz}}$ in the 1–10 Hz band, successfully matching FBA performance levels while avoiding the mathematical nonlinearity inherent to capacitive MEMS analog signal chains. The hardware-based STM32 timer design achieved a PPS-to-sync synchronization precision of under 5 microseconds. By handling strictly digital data, the integrated system completely removes the need for external ADCs. This architectural shift miniaturizes and simplifies the system, while eliminates the intensive manual labor previously required for tuning ADC gains and compensating for analog sensitivity variations, drastically reducing both measurement setup time and total hardware costs.

Conclusions. This integrated system, combining a high-sensitivity Quartz-resonant MEMS transducer with hardware-driven GNSS synchronization, represents a significant advance at the intersection of mathematical signal processing and practical sensor engineering. Eliminating analog signal chains, ADC dependencies, and software-based timing jitter yields a highly linear, easily deployable measurement node. This robust, cost-effective digital architecture empowers researchers and industry professionals to seamlessly execute high-precision, large-scale SHM deployments.

Summary Points.

- We developed an integrated Quartz-resonant MEMS accelerometer system achieving 550 Hz/g sensitivity and 20 ng/$\sqrt{\text{Hz}}$ noise density.

- The entire system, including the hardware-based GNSS synchronization board and the sensor, operates at around 100 mA (3.3 V) per node while guaranteeing under 5 microseconds timing precision.

- Direct digital output completely eliminates ADCs, bypassing tedious analog sensitivity calibration and gain adjustments.
- The compact and streamlined system architecture reduces setup time and hardware costs, facilitating scalable industry-academia monitoring projects.
→ *Full program*

A Scalable Framework for Simultaneous Optimization of Damper Placement and Viscosities

Zoran Tomljanović, School of Applied Mathematics and Informatics University of Osijek

Abstract. We consider damping optimization for vibrating systems described by a second-order differential equation. The problem of damping optimization has been widely studied in recent decades and is typically considered in two different settings: for homogeneous systems and for non-homogeneous systems, i.e., systems excited by external forces. In the most general setting, the problem can be formulated as follows. For given mass and stiffness matrices, we aim to determine an external damping matrix such that unwanted vibrations decay as rapidly as possible. For this purpose, given a fixed number of dampers, our goal is to determine their optimal positions and viscosities. In addition, when considering homogeneous systems, a higher-level question arises: how to determine the optimal number of dampers so as to minimize a given optimization criterion up to a prescribed accuracy. This question can be combined with the problem of determining the corresponding optimal positions and viscosities. In this work, we focus on the homogeneous case and consider the minimization of the total average energy of the system. We propose a new framework for determining both the number and the positions of the dampers, based on relaxed weighted (l_1) minimization and pruning techniques. The efficiency and performance of the proposed approach are demonstrated through several numerical examples.
→ *Full program*

Index

Aidoo, Isaac Kweku, 52
Al-Hadeethi, Farqad, 52
Al-Hamdan, Qusai Z., 47
Arjmand, Doghonay, 20
Asfaw, Manalebish Debalike, 31
Asif, Mu'izz, 31
Asokan, Reshma Pindiyathpady, 44
Ayyalasomayajula, Kalyan Ram, 14
Azhar, M. Uzair, 48

Bayazid, A K M, 39
Berg, Patrick Norheim, 39
Bhalla, Suresh, 9
Bhandari, Dila, 53
Birdac (Fildan), Lavinia Florina Rodica, 35
Birnir, Björn, 9
Bjerknes, Ann Kristin, 40
Bocci, Alessio, 32
Boiger, Gernot, 25
Borissova, Ana Vassileva, 48
Braides, Andrea, 30
Brincker, Rune, 10

Corona Sanchez, Jose Juan, 20

Dal Maso, Gianni, 10
Dang, Nga, 44
Das, Sovik, 49
Derso, Rekik, 53

Ejigu, Fasil E, 45
Enerbäck, Jenny, 35
Entner, Erlend, 45
Evgrafov, Anton, 29

Fahimi, Pouya, 14
Fallah, Arash Soleiman, 10
Feichtinger, Hans Georg, 11
Finke, Martha, 54

Gaur, Gulshan Kumar, 54
Geleta, Hunduma Legesse, 21
Gupta, Shakti, 25

Henriksen, Tanja, 21
Huynh, van Khang, 17

Jain, Pankaj, 32
Jankowsky, Alina, 21

Kaltenbacher, Barbara, 11
Kapoor, Kanish, 49
Kaslik, Eva, 36
Khader, Safa, 45
Konjik, Sanja, 36
Kosmač, Aljaž, 22
Kumar, Nitin, 26

Lakdawala, Zahra, 54
Lakså, Arne, 22
Lasserre, Jean-Bernard, 12
Londoño Orozco, Mariana, 32

Madaan, Jitender, 50
Malila, Jussi, 50
Malmberg, Filip, 14
Mascarin, Francesco Maria, 23
Mishra, Anurag, 46
Mohammadreza, 40
Muntean, Adrian, 12
Munthe-Kaas, Hans, 23
Mustafa, Mohamad, 26

Nabi, Rao Adeel Un, 26
Nazari, Afshin, 17
Nedic, Mitja, 30
Nguyen, Hoang, 36
Nwamma, Macdonald, 40
Nylund, Dag, 37

Okabe, Satoshi, 13
Otsiwah, Ephraim Nyarko Ebo, 55

Palavai, Sowmya Sree, 17
Panasenko, Grigory, 30
Patel, Ajay Singh, 41
Patil, Aniket Chandrakant, 27
Patil, Ravindra R, 15
Petrich, Christian, 41
Piatnitski, Andrey, 30
Pichika, S V V Srihari, 18
Pick, Luboš, 13

Quarchioni, Simone, 42

Raju, Penupothula, 55
Ratsaby, Joel, 23
Redoy, Md Daudul Islam Bhuiyan, 18
Rodriguez Velasco, Rafael, 37
Rouillier, Fabrice, 23

Samko, Natasha, 33
Sawano, Yoshihiro, 33
Schilders, W.H.A. (Wil), 13
Schlanbusch, Rune, 42
Scholtz, Laura-Kristin, 56
Sinha, Sadanand, 56
Spina, Daniele, 42
Srivastava, Amber, 15
Storni, Daniele, 43

Taief, Abu Mohammad, 56
Taj, Samad Ali, 50
Tangrand, Kristoffer, 15
Tedla, Segid, 18
Tephnadze, George, 29
Thakur, Somil, 51
Thanh, Hung Nguyen, 51
Todorokihara, Masayoshi, 57
Tomljanović, Zoran, 58
Turčinová, Hana, 33
Tutberidze, Giorgi, 29

Uddin, Ziya, 37
Upreti, Himanshu, 27

Vaseem, Mohd, 27
Vitrih, Vito, 24
von Bargen, Kevin, 24

Wally, Youssef, 16

Yagoubi, Mohamed Riad, 33
Yashwant, 51
Yeshitla, Etsehiwot, 33

Ågotnes, Joachim Jørgensen, 34

Łukasik, Radosław, 55