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2025 *Activity Report*

RESEARCH CENTRE: **Inria Centre at Rennes University**

IN PARTNERSHIP WITH: **Université Gustave Eiffel**

Project-Team

I4S

Inference for Intelligent Instrumented InfraStructures

In collaboration with Département Composants et systèmes

Project-Team I4S

Creation of the Project-Team: 2024 November 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

A5.9.2. – Estimation, modeling

A5.9.6. – Optimization tools

A6.1.2. – Stochastic Modeling

A6.1.4. – Multiscale modeling

A6.1.5. – Multiphysics modeling

A6.2.1. – Numerical analysis of PDE and ODE

A6.2.4. – Statistical methods

A6.2.5. – Numerical Linear Algebra

A6.2.6. – Optimization

A6.2.8. – Computational geometry and meshes

A6.3. – Computation-data interaction

A6.3.1. – Inverse problems

A6.3.2. – Data assimilation

A6.3.3. – Data processing

A6.3.4. – Model reduction

A6.3.5. – Uncertainty Quantification

A6.4.3. – Observability and Controlability

A6.5.1. – Solid mechanics

A6.5.2. – Fluid mechanics

A6.5.3. – Transport

A6.5.4. – Waves

A9.2. – Machine learning

A9.2.1. – Supervised learning

Other research topics and application domains

B3.1. – Sustainable development

B3.2. – Climate and meteorology

B3.3.1. – Earth and subsoil

B4.3.2. – Hydro-energy

B4.3.3. – Wind energy

B5.1. – Factory of the future

B5.2. – Design and manufacturing

B5.2.1. – Road vehicles

B5.2.2. – Railway

B5.2.3. – Aviation

B5.2.4. – Aerospace

B5.5. – Materials

B5.9. – Industrial maintenance
B6.5. – Information systems
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B7.2.2. – Smart road
B8.1. – Smart building/home
B8.1.1. – Energy for smart buildings
B8.1.2. – Sensor networks for smart buildings
B8.2. – Connected city
B9.5.3. – Physics
B9.5.5. – Mechanics

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2 Overall objectives

2.1 Context

The design, monitoring and maintenance of engineering structures subject to noise and other environmental perturbations are important aspects of research. The goal is to ensure efficient operation, safety, durability and sustainability, while the structures are aging under increased loads and environmental burdens, or even passing their design life. This concerns, to name a few examples, classic civil structures like bridges or buildings, more recent structures like wind turbines, or new designs based, e.g., on meta-materials. For such structures, *Structural Health Monitoring* (SHM) has the goal to continuously assess their state – and in particular the appearance of faults/damages or any other abnormal behavior – based on dynamic response measurements from an array of sensors. In particular, an automated and online structural assessment allows optimized maintenance, avoids critical failure, increases safety and extends the lifetime of structures.

Strongly connected to the data-based evaluation of structures is structural analysis and design, with the purpose to understand, to predict and to optimize structural behavior, to infer structural changes based on monitoring data, and to efficiently monitor new designs. The monitoring technology itself has evolved rapidly in the last decade and has become affordable, allowing the large-scale instrumentation of critical structures. Besides classical sensors that are attached to a structure (e.g., accelerometers, fiber optics), the technology for vision-based full-field measurements has become available very recently (e.g., video-based vibration measurements, infrared thermography).

Indeed, the rising consideration of physical model information, together with the availability of full field sensing technologies, enable a change of the SHM paradigm for our team project. Previously, the main focus of SHM was the estimation of dynamic system parameters and the detection of changes therein under environmental nuisance, based on measurement data from sparse sensor instrumentations, and with the purpose of statistical decision making to infer if there is a change or not. Now, SHM can envisage the much larger goal of *monitoring the full structural state*, moving towards a *digital twin* of the monitored structure. For such an online assessment of the structural state, the information from the measurement data need to be fused with the physical information from possibly *complex* structural models, where the ultimate goal is structural performance analysis, prediction and optimization. Here, *complex* indicates the departure from *simple* finite element modeling of linear vibration behavior that is classically used in the domain of SHM, to more realistic (and complex) modeling of the physical phenomena characterizing the structural behavior, involving, e.g., wave propagation, aerothermics, multi-physics modeling including thermal behavior, non-linear dynamics, thermodynamics, cyber-physical systems, etc.

The I4S team aims at addressing the whole chain of SHM in a holistic approach, including the exploitation of new sensor technologies, physical modeling for structural analysis and design as well as measurement data-driven analysis of the dynamic systems, which together give rise to digital twinning and performance prediction by fusing measurement data with physical models. The team is characterized by its multidisciplinarity between physical modeling, statistical signal processing and engineering applications, where a strong interaction between the aforementioned aspects is a key to the success of SHM.

The I4S team is affiliated to Université Gustave Eiffel, where it is part of the COSYS (Components and Systems) department in the SII (Instrumented Structures and Systems) laboratory. The COSYS department consists of nine laboratories with the overall goal to develop the concepts and tools needed to improve the basic knowledge, methods, technologies and operational systems required for the renewed intelligence of mobility, infrastructure networks and major urban systems. The SII laboratory is concerned with the development of concepts and methods for instrumentation and structural monitoring. Besides the shared research road map with COSYS-SII, a particular benefit for I4S is the access to experimental measurement and testing facilities for proofs of concept and benchmarking, which are commonplace in civil engineering labs but not at Inria. This allows the I4S team to complement theoretical developments with experimental validation, and facilitates transfer.

In this context, the team project contributes to societal challenges on green and sustainable infrastructures, where *smart monitoring* reduces the energy consumption of infrastructure during operation, reduces downtime, and optimizes and prolongs the service life of structures. Furthermore, the final goal of *smart structures* is low energy consumption of the structure (during construction and operation) as well as durability over time, based on robust designs allowing optimized monitoring and diagnosis.

2.2 General objective

The general objective of the I4S team is the design of autonomous and robust methods for SHM – i.e., characterization of their state, the characterization of structural changes over time, and the structural performance assessment and prediction – based on measurement data and physical models. Herein, robustness is a key to practical relevance and addresses different aspects, such as noise, environmental nuisance, or numerical feasibility or stability of methods, e.g., when dealing with very complex physical models or new full-field measurement systems involving now thousands or millions of outputs to be processed.

In order to understand the structural behavior based on measurement data, structural analysis and design are becoming an important part of the research activity, with the goal that SHM methods exploit both data and the related physical models in an optimal way. Besides the consideration of classical linear structural behavior that reasonably approximates a wide range of structures (e.g., most bridges, buildings), other structures show some intrinsic non-linear behavior (e.g., wind turbine structures), or damages to be monitored can induce non-linear behavior (e.g., cracks, joints). It is therefore the objective to investigate and to consider relevant non-linear phenomena in structural analysis and monitoring methods. On the other side, the structural design itself is an objective in the context of monitoring, e.g., for meta-structure engineering with designed properties regarding vibration and noise – and their monitoring –, or more general, for coupling design with monitoring for the conception of *smart structures*.

With the structural modeling at hand, it is the objective to conceive statistical methods that fuse data and models for an advanced assessment of the structural state. The overall goal is to conceive techniques for digital twins, based on real-time multi-physics and multi-data analysis integrating diverse measurement sources for a complete structural assessment.

Being a multidisciplinary team with strong applications in engineering, we have the general objective to develop theoretical methods that are motivated by applications, and to deliver their proofs of concepts on laboratory and field applications, including the development of demonstrators and their transfer to industrial partners.

3 Research program

The scientific challenges to achieve our objectives of SHM are addressed by five research axes of the team:

Axis 1: Sensor technologies and data harvesting concerns the characterization and usage of new sensor technologies for monitoring. An important topic is the exploitation of data for subsequent monitoring methods, e.g., by developing image processing methods for active or passive imaging in the visible or infrared range. Another challenge is smart sensing, e.g., with self-diagnosis of sensors on the quality of the measured signals over time.

Axis 2: Complex physical models for structural analysis and design focuses on multi-physics modeling. The challenge is to understand various phenomena occurring at different scales in structures, in order to optimize their design, performance, identification and monitoring. The fields and scales of physics intersect in these issues, including couplings between mechanical and thermal behavior, or dynamics and acoustics. The approaches to be developed make extensive use of numerical resolution schemes and multi-scale or model reduction methods.

Axis 3: Advanced data analysis for complex systems concerns processing techniques of measurement data to infer structural properties under simplifying assumptions (e.g., linear model structure) and without the use of physical model properties. The challenge is to extract relevant information for characterizing a structure (e.g., vibration mode) or a material (e.g., wave velocity, permittivity) under environmental nuisance, and to track these parameters over time, which enables data-driven monitoring. This calls for statistical system identification and Bayesian filtering techniques, as well as AI-based processing tools.

Axis 4: Joint data/model analysis – digital twin focuses on fusing measurement data with physical model information for an advanced structural assessment. The main challenge is the optimal processing of information from various sources (multi-physics modeling, data from different kinds of sensors) under both model and estimation uncertainties, and at different scales (material, component, whole system). Physics-informed machine learning will play an important role.

Axis 5: Predictive analysis concerns the prognosis of future behavior of the monitored system. A first challenge is the predictive analysis of the actual diagnosis performance, i.e., detectability or identifiability, of an employed monitoring system (comprising sensors and diagnosis methods), while data from damaged systems is usually never available in advance, models are flawed, and sensors are degrading over time. This leads to structural performance assessment, where the ultimate goal is the prediction of the remaining useful service life.

4 Application domains

The theoretical and technological developments of the team are motivated by structural health monitoring applications. An important application focus is on the assessment of civil structures like bridges or buildings, as well as wind turbine monitoring. In general, infrastructure is of interest, including urban structures (heat islands), railway structures or energy related infrastructures (cables, power lines).

Besides these more classic application domains of the team, the design and monitoring of advanced structures and materials is an emerging topic, with applications to various industries (e.g., transportation, aerospace, naval and civil engineering). One can mention the development of lightweight locally resonant material concepts to enhance the sound transmission loss in an aircraft fuselage, or the material identification of composite structures using non-contact measurement techniques. Furthermore, the modeling and optimization of novel mechanical architectures able to mitigate low-frequency and/or seismic loads is a promising research avenue. The design and analysis of materials with particular properties for heat transfer, like porous media and/or phase change materials, becomes of interest, with applications to thermal regulation of materials, structures or urban districts. Another advantage of these enhanced properties is their use and analysis under ambient thermal loading, revealing information about structure through a different prism: a structural health via energetic monitoring. Furthermore, the analysis and monitoring of non-linear phenomena on structures, e.g., due to contact, friction, slender geometries or interactions between various physics (e.g., fluid structure interactions) are emerging, with applications to wind turbines, railways, mechanical or aeronautical systems, among others. Last but not least, the ongoing collaboration with the Hycomes team paves the way toward the health monitoring and optimal control of complex multi- and cyberphysical systems such as power grids and urban heating networks.

Thanks to the interaction between physical models and data, the developed techniques are rarely limited to a particular structure. The methodological expertise of the team could also open up to applications in completely new areas, like for monitoring bio-mechanical structures and engineering components, ranging from the nanoscopic (e.g., crystals) to the macroscopic scales (e.g., seismic).

5 Highlights of the year

The I4S team has organized the IOMAC 2025 conference at the Inria Rennes conference center from May 20–23, 2025, attracting 150 participants.

5.1 Awards

- Former PhD student Cédric Bertolt Nzouatchoua was awarded the Special Mention “Environmental Sensitivity and Innovation” in the 2025 Thesis Prize of the Le Mans University Foundation.
- PhD student Lucas Rouhi got the Best PhD Paper Award for the article "Controlling dispersion in lattice waveguides using positive-stiffness-only non-local interactions" [54] at the 16th International Conference on Vibration Problems (ICOVP-2025) & 11th International Conference on Wave Mechanics and Vibrations (WMVC-2025), held in Lisbon, Portugal, on September 2–5, 2025

6 Latest software developments, platforms, open data

6.1 Latest software developments

6.1.1 Supervisor

Name: Supervisor

Keywords: Middleware, Sensors, Python, Digital twin, SHM (Structural Health Monitoring), Control system

Functional Description: Supervisor is a middleware designed for efficiently handling data fetched from sensors or online sources, backing up this data in a secure manner, and launching calculation programs in a synchronized way.

Release Contributions: First complete version.

Contact: Jean Dumoulin

Participants: Jean Dumoulin, Thibaud Toullier, Mathias Malandain, 3 anonymous participants

Partner: Université Gustave Eiffel

6.1.2 Spycic

Name: Spycic library

Keywords: Python, C++, Binding

Scientific Description: Spycic is a header-only C++ library for fetching and calling Python functions from C++ code. Designed as a wrapper of the C/Python API, Spycic strongly relies on variadic templates to make it possible to call in a simple way Python functions with different signatures and an arbitrary number of arguments. GIL handling, exception handling and type casting are performed under the hood, so as to make use as simple as possible.

Functional Description: The Spycic (Simple Python Calls In C++) header-only library is a wrapper around the C/Python API that provides a handful of functions allowing for simple calls to Python functions from a C++ code. Python functions to be used may be declared in several *independent* source files.

Spycic provides the following functions:

* ‘fetchFunction(const char* functionName, const char* sourceCode)‘ is used to fetch the Python function called ‘functionName‘ from a given Python code ‘sourceCode‘ provided as a C-style string. The function is returned as a ‘PyObject*‘. * ‘fetchFunction(const char* functionName, std::string& sourceCode)‘ is used to fetch the Python function called ‘functionName‘ from a given Python code ‘sourceCode‘ provided as a ‘std::string‘. The function is returned as a ‘PyObject*‘. * ‘runFunction<returnType>(PyObject* func, Values... values)‘ is used to call a Python function (imported as a ‘PyObject*‘) with an arbitrary number of arguments. The return type has to be specified as a template argument, for example, ‘runFunction<double>(f, arg1, arg2)‘. The return type can be ‘void‘, as in ‘runFunction<void>(f, arg1, arg2)‘. All necessary operations (GIL handling, formatting, type castings, etc.) are performed under the hood. The arguments are provided as C++ POD (Plain Old Data) values and/or ‘std::vector‘ containers, and the output (if any) is a C++ POD or vector as well.

A fresh exception class called ’PythonError’ is also defined in order to handle errors that occur during calls to functions provided by the C/Python API itself.

Client code must still call functions ‘Py_Initialize()‘ and ‘Py_Finalize()‘ to be able to use the Python interpreter.

Release Contributions: The handling of ‘std::vector‘ objects (containing floating point numbers or integers) as both function inputs and function outputs, and the handling of functions returning ‘void‘, were added since version 0.1.

News of the Year: Regroupement sous la forme d’une bibliothèque header-only, appels transparents de fonctions ne retournant aucune valeur, vérification des overflows lors du casting de valeurs de retour (Python vers C), mémoisation pour l’import des modules, pipeline CI, passage en REUSE-compliant en vue d’une ouverture open source.

Contact: Mathias Malandain

Participant: Mathias Malandain

6.1.3 PythonFMUGenerator

Keywords: Cosimulation, FMI, Cyber-physical systems

Scientific Description: PythonFMUGenerator is a tool for the automatic encapsulation of Python code into C++-based standardized cosimulation units (FMUs). It only relies on a Python source file and a JSON description of the properties of the generated FMU. This makes it possible to integrate on-demand FMU generation to a system model assembly and simulation pipeline, contrary to existing tools that create templates to be populated by hand before compilation and FMU generation.

Functional Description: FMI is a fast-growing standard for the cosimulation of large mutli- and cyberphysical system models. It relies on the encapsulation of source code, written in various tools and languages, into cosimulation units called FMUs that share a common interface. However, the encapsulation of Python code into an FMU is still a technical challenge that very few tools try to address.

PythonFMUGenerator is a tool for the automatic encapsulation of Python code into C++-based FMUs for cosimulation. It only relies on a Python source file and a JSON description of the properties of the generated FMU. This makes it possible to integrate on-demand FMU generation to a system model assembly and simulation pipeline, contrary to existing tools that create templates to be populated by hand before compilation and FMU generation.

PythonFMUGenerator relies on the Spycic library (from the same author), that acts as a wrapper around the C/Python API so as to considerably simplify Python function calls from C or C++ code. It is based on FMICodeGenerator, a tool developed by Andreas Nicolai (ghorwin) and coworkers, itself under a BSD3 license.

News of the Year: Passage au standard FMI3 (API intégrale + logiques d'exécution pour l'initialisation, l'avancement temporel et l'entrée/sortie de valeurs de tous les types gérés par le standard), gestion des vecteurs en entrées/sorties des FMU, pipeline CI pour de nombreux tests de l'intégralité de la chaîne de génération des FMU.

Contact: Mathias Malandain

Participants: Benoit Caillaud, Mathias Malandain, Thibaud Toullier

7 New results

7.1 Sensor technologies and data harvesting

7.1.1 Strain Transfer Modeling and Post-Processing for Distributed Fiber Optic Sensors

Participants: Mira Kabbara, Xavier Chapeleau, Qinghua Zhang.

Distributed fiber optic sensors are widely used in structural health monitoring due to their high spatial resolution. Accurate interpretation of their measurements requires careful consideration of strain transfer through protective coatings. A simplified one-dimensional strain transfer model, incorporating a strain lag parameter dependent on cable properties and installation conditions, has been commonly used. This study extends the model to robust four-layered cables, including steel-reinforced and polymer-coated designs, and assesses its performance under strain gradients using finite element simulations. Results show that the model accurately predicts strain in steel-reinforced cables but is less precise for polymer-coated cables, highlighting the importance of interlayer stiffness and strain lag calibration.

To enable practical use in high-resolution measurements, efficient post-processing algorithms are developed to solve the 1D strain transfer equation and its inverse problem. These methods allow rapid reconstruction of the actual strain profile from raw sensor data, supporting applications such as real-time vibration analysis and structural health monitoring. Together, the modeling and post-processing framework improves both the accuracy and usability of fiber optic sensors in complex environments. [24, 47]

7.1.2 Subpixel motion estimation for video-based target-free vibration monitoring under complex environmental conditions

Participants: Zhilei Luo, Boualem Merainani, Vincent Baltazart, Qinghua Zhang, Michael Doehler.

An emerging technique to measure structural vibrations is based on motion signals extracted from video images. The use of video cameras offers multiple advantages over traditional mechanical sensors: contactless measurement, large coverage, easy installation and maintenance. This work proposes a new method for real-time motion signal extraction from video images with subpixel accuracy. It aims to address the challenges posed by complex operating conditions, namely illumination variations and background interference. Illumination robustness is achieved by efficiently combining image intensity interpolation with an affine brightness and contrast tuning transformation. Background robustness is obtained by automatically selecting active pixels in the processed images. Moreover, the on-line numerical computations are fast enough for real-time applications. Results of theoretical analysis ensure that the considered optimization criteria are well-posed and that, in the main step of subpixel motion estimation, the involved nonlinear optimization problem is efficiently solved in closed-form through a linear least squares problem. The performance of the proposed method is evaluated both on simulated images and on laboratory experiments with a target-free cantilever beam in comparison with existing methods. The reported results demonstrate the robustness and computational efficiency of the proposed method under complex environmental conditions, allowing real-time computation on a standard laptop for vibration monitoring with more than 100 virtual sensors at 600 frames per second. [25]

7.1.3 Monitoring for sustainable and inclusive urban areas

Participants: Jean Dumoulin.

Urban resilience requires continuous monitoring of critical services and infrastructure to respond effectively to hazards and multi-risk scenarios, including climate change and pandemics. Advanced monitoring approaches now integrate Earth observation, positioning, navigation, ICT technologies, and citizen-sourced or “non-sensor” data to enhance situational awareness. By combining these diverse data streams and processing them with artificial intelligence and high-performance computing, cities can achieve more informed intervention planning, improved service continuity, and ultimately safer, smarter, and more inclusive urban environments. [55]

7.1.4 Ozone Concentration Estimation from Infrared Images Using Extinction Coefficient

Participants: Jean Dumoulin.

Air quality assessment requires concentration measurement of various polluting gases, typically requiring multiple expensive sensors, each dedicated to a specific pollutant. Therefore, there is a need for costeffective sensors capable of detecting one or more pollutants, with less reliability, such as camera-based sensors, but enabling denser sampling. In this work, we investigate how the extinction coefficients estimated from an infrared camera may be useful for predicting ground-level ozone concentration. In addition to these coefficients, we show how weather and pollution measures collected from stations near the studied area are useful, with different machine learning methods, to better predict ozone concentration. The performance of the models is validated through a comprehensive evaluation using MAE, RMSE and R-Squared metrics. Parameter selection methods are also used to study the impact of different meteorological parameters and other pollutant concentrations on the prediction of ozone concentration. [42]

7.1.5 Outdoor Hybrid Solar Road Demonstrator Monitoring Using Infrared Thermography with Embedded Local Probes for Energy Harvesting Performance Evaluation

Participants: Jean Dumoulin, Domenico Vizzari, Lucas Czamanski Meireles, Thibaud Toullier.

This study investigates, in a natural environment, the thermal behavior of an innovative pavement system with thermal and solar energy collection functionalities. The whole structure is continuously monitored using temperature and heat flux sensor probes integrated inside the structure. Local weather conditions are also monitored. Infrared Thermography is used as a complementary non-invasive technique to monitor temperature surface distributions with time and assess the efficiency of heat transfer within the pavement structure. All sensors are connected to a newly developed platform that centralized data access, visualization, and storage, enabling seamless management and user interactions. The obtained results are presented and discussed. [43]

7.1.6 Comparative study of image quality acquired on a new portable dynamic laboratory test bench using two thermal time constant uncooled IRFPA microbolometric camera

Participants: Boualem Merainani, Thibaud Toullier, Jean Dumoulin.

An experimental setup dedicated to assessing and comparing the image quality of uncooled IRFPA microbolometer cameras with different thermal time constants has been designed and realized. Initially, we explored a concept involving heated objects mounted on two opposing arms rotating at different temperatures; However, practical constraints, such as the need for electrical brushes to transfer current, as well as significant challenges related to mass balance and installation complexity, made this approach impractical. Consequently, we adopted a new solution comprising fixed thermal panels and a self-designed rotating disk inspired by optical choppers. We designed the test bench to be compact and portable, enhancing its versatility and making it adaptable to various testing environments. Figure 1 illustrates both the CAD design and the real implementation of the test bench. [51]

7.1.7 PEGASE4 : a generic board for embedded SHM applications

Participants: Vincent Le Cam, Arthur Bouché, Adji Toure, Antoine Barre, Lucas Doula.

This work presents the latest version of PEGASE, a versatile wireless board designed for Structural Health Monitoring (SHM) applications. The first part highlights the technological advances of PEGASE, including its generic processing capabilities with an embedded Buildroot Linux system, an inertial measurement unit (IMU), GNSS receivers, and multiple I/O interfaces. The discussion then focuses on key scientific innovations, such as the novel use of the GNSS/PPS signal to achieve microsecond-level synchronization within Linux, and energy management strategies optimized for efficient battery and solar-cell usage. Finally, practical SHM applications are presented to illustrate PEGASE in action, including its deployment in a wireless acoustic emission monitoring system. [48]

7.1.8 Advanced optical and distributed sensing for monitoring interfaces and structural behavior

Participants: Arij Fawaz, Xavier Chapeleau.

Recent developments in fiber-optic and distributed sensing technologies are enabling new strategies for monitoring interfaces, durability, and load transfer mechanisms across structural and material systems. These contributions illustrate how embedded and bonded optical sensors can provide high-resolution measurements under static, cyclic, and dynamic loading conditions.

Fiber Bragg Grating (FBG) sensors were embedded in castable polyurethane resins to evaluate their suitability for ultrasonic applications. The study examined strain evolution during polymerization and showed spectral shifts of up to 10 nm, highlighting the need to account for material shrinkage when selecting interrogation wavelengths. After curing, FBGs successfully detected 100 kHz ultrasonic waves, with acrylate and polyimide coatings transmitting comparable energy to the fiber core, and preliminary signs of possible crosstalk between gratings. These results confirm the feasibility of using embedded FBGs for ultrasonic sensing in castable materials. [21]

A new adhesively bonded specimen configuration was developed to allow both creep testing and fracture-mechanics characterization within the same geometry. The End-Loaded Split (ELS) test was adapted for mode II fracture, while the creep frame ensured a constant stress state in the adhesive layer. Digital Image Correlation and optical fiber sensors were used together to monitor crack propagation and evaluate energy release, enabling more consistent assessment of bonded joints before and after creep aging. [44]

Full-scale experimental pavement sections were instrumented to study the response of surface layers under different axle configurations and interface bonding conditions. Strain gauges and embedded optical fibers placed at several depths captured the influence of temperature, wheel interaction, and debonding on strain fields. Tridem axles generated higher strains than single axles, and interface debonding led to tensile strains at the bottom of the surface layer, contrasting with compressive strains in well-bonded cases. Numerical simulations using Viscoroute 2.0 supported the interpretation of these measurements. [18]

Finally, the bond behavior of thermoplastic GFRP rebars embedded in concrete was examined through pull-out testing. The effects of rebar diameter and surface geometry on force–displacement response and average pull-out strength were analyzed, and some specimens were equipped with optical fiber cables to record strain distributions along the interface in real time. Comparisons with thermoset GFRP and conventional steel reinforcement provided further insight into differences in bond mechanisms and durability potential. [45]

7.2 Complex physical models for structural analysis and design

7.2.1 Optimizing bifurcations and singularities for performance enhancement and mitigation of the adverse dynamics of nonlinear energy sinks

Participants: Adrien Mélot.

This work introduces a general computational framework for optimizing the performances and mitigating the adverse dynamics of nonlinear energy sinks (NESs) under harmonic external forcing. It is well known that attaching small, essentially nonlinear, subsystems to a linear host system can provide efficient passive vibration mitigation. However, the introduced nonlinearity can induce adverse dynamics, in the form of isolated response curves, which are detrimental to the performances of the system. Several multi-objective optimization problems are formulated, which consist in minimizing objective functionals derived from bifurcation and singularity theory in order to control such phenomena and improve the performances of NESs. The methodology is demonstrated on a two-degree-offreedom system consisting of a linear oscillator coupled to a nonlinear energy sink with cubic stiffness. However, its fully computational nature makes it applicable to arbitrarily complex NES configurations and lays the foundation for extending the design optimization of NESs to full finite element models. These results are compared to those obtained with the inclusion of a nonlinear damping term, which is a common way of mitigating the issue of isolated response curves in the literature. We report significant computational speedups compared to existing methodologies for controlling isolated response curves induced by nonlinear energy sinks. [30, 60]

7.2.2 An efficient neural network-based surrogate model for predicting static gear contact conditions

Participants: Adrien Mélot.

Gears are an essential component of numerous mechanical systems across a wide range of engin-eeringapplications. However, they may be associated to high levels of radiated noise which can limit their use.Accurately predicting this noise is of paramount importance for the design, optimization and health mon-itoring of gear transmissions. System identification is therefore needed to reach a sufficiently high levelof accuracy. However, this usually comes at the cost of high computational burden. Using traditionalmodeling assumptions, it is widely accepted that the radiated noise stems from the dynamic response ofthe gears which is itself induced by the static transmission error (STE) and time-varying mesh stiffness.These physical quantities are governed by the local contact conditions between the gear teeth. An accu-rate computation of these physical quantities is therefore crucial. However, this is a difficult problem asgear contact resolution is intrinsically nonlinear and multiscale. Even considering simplifying assump-tions, the computation of this physical quantities entails a significant computational effort when coupledto optimization procedures. In this work, we introduce an efficient neural network-based surrogate modelfor predicting static gear contact conditions in near real time in order to facilitate the identification andoptimization of mechanical systems equipped with geared systems. [52]

7.2.3 Computing the dynamic response of periodic waveguides with nonlinear boundaries using the Wave Finite Element Method

Participants: Vincent Mahé, Adrien Mélot, Christophe Droz.

Nonlinear effects are increasingly relevant in modern mechanical systems due to lighter, slender structures and the desire to exploit nonlinearities for enhanced performance. Accurately capturing these effects is challenging, as numerical models of periodic waveguides can involve millions of degrees of freedom, and localized nonlinearities further complicate simulations. This work proposes an extension of the Wave Finite Element Method (WFEM) that combines Floquet-Bloch theory with finite-element discretisation of complex unit cells, enabling efficient computation of the dynamic response of periodic waveguides with nonlinear boundaries. Nonlinear forces are treated via an alternating frequency-time procedure and higher harmonics are captured using the Harmonic Balance Method, with the system solved through numerical continuation.

The method reduces problem size while providing richer physical insight than classical finite element approaches. Validation against standard FEM with Craig-Bampton reduction shows excellent agreement and an 83% reduction in computational time. Application to a locally resonant metamaterial demonstrates that nonlinear effects can shift band-edge resonances into bandgaps, producing high-amplitude, spatially localised vibrations not predicted by linear theory. This approach offers a versatile and efficient framework for simulating complex metamaterials, civil engineering structures, and other systems with nonlinear interfaces or singularities, supporting system identification, R&D cycles, and digital twinning applications. [29, 50, 59]

7.2.4 Reduced Frequency-driven Bloch Wave Decomposition for Harmonic Analysis of Finite Periodic Structures

Participants: Christophe Droz, Alvaro Gavilan Rojas.

A frequency-driven, reduced wave finite element method is proposed for periodic structures which are solely defined by their dynamic stiffness matrices. Using an S-S^{-1} transform combined with an adaptive eigenvector sampling and a ω-driven Bloch wave decomposition, we achieve dispersion and harmonic analyses with enhanced accuracy and efficiency. [36]

7.2.5 Controlling dispersion in lattice waveguides using positive-stiffness-only non-local interactions

Participants: Lucas Rouhi, Christophe Droz.

This study presents a systematic approach to engineering the dispersion relation of one-dimensional monoatomic lattices through the use of long-range interactions constrained to strictly positive stiffness values. Departing from classical cosine fitting techniques, the proposed framework employs interpolation at prescribed frequency-wave number pairs, leading to a linear system formulation. The stiffness coefficients are then determined using non-negative least squares, ensuring the physical admissibility of the design. This method enables the realization of dispersion curves featuring nonstandard characteristics, such as negative group velocity, roton-like stationary points, or locally flat bands, without resorting to non-physical parameters. The concept of admissibility domains is introduced to characterize the feasible set of target values under positivity constraints, and several numerical examples illustrate the trade-offs between design flexibility and physical realizability. The framework provides a versatile tool for the inverse design of dispersion in non-local lattices, with potential extensions to higher-dimensional and multi-physical systems. [54]

7.2.6 Adjustable surface tension independent of the collision operator for pseudo-potential lattice Boltzmann methods

Participants: Romain Noel.

In this work, we propose an alternative surface tension adjustment approach in the pseudo-potential lattice Boltzmann (LB) model, which is not only decoupled from the density ratio but also independent of the collision operator. This is achieved by incorporating a generic source term obtained from the difference between a modified moment equilibrium and an original moment equilibrium distribution function in the LB equation. The explicit form of the source term is obtained through a third-order Chapman-Enskog analysis of the LB equation, aiming to recover the targeted governing equations from a modified Landau free energy theory using a hybrid density-pseudo-potential form. The source term can be easily and straightforwardly incorporated into different widely used collision operators, such as single relaxation time (SRT or LBGK), multiple relaxation time (MRT) and entropic-MRT (KBC) operators. The proposed method is validated by three benchmarks: (i) the liquid-gas co-existence density, (ii) surface tension adjustment via the static droplet case and (iii) droplet deformation via oscillations. It is shown that thermodynamic consistency is restored in a large range of temperature ratio, and, moreover, a remarkable tunable surface tension range of 140 times can be achieved. Benefiting from the proposed surface tension adjustment method, we have successfully modeled the droplet impact and splashing dynamics with a Weber number up to 10 500, achieving one order of magnitude higher than LB simulations reported in the literature. [31]

7.2.7 Topology Optimization of Isolated Response Curves in 3D Geometrically-nonlinear Beam

Participants: Adrien Mélot.

Topology optimisation is a powerful tool for designing efficient and light structures. However, classical topology optimisation methods (SIMP, LSF), which are gradient-based, are not adapted to deal with nonlinear vibrations in the context of geometrical nonlinearities as the simulation of such systems is computationally expensive, and the strong nonlinearbehaviour makes the objective function non-convex with many local minima. The present work investigates the potential of using global optimisation methods to topology optimise those structures. To provide more robust nonlinear features in the optimisation, the bifurcations are directly tracked and optimised. The strategy is applied to a 3D finite element model of a beam [41]

7.3 Advanced data analysis for complex systems

7.3.1 Variance estimation of modal parameters from the poly-reference least-squares complex frequency-domain algorithm

Participants: Mikkel Tandrup Steffensen, Michael Doehler.

Modal parameter estimation from input/output data is a fundamental task in engineering. The poly-reference least-squares complex frequency-domain (pLSCF) algorithm is a fast and robust method for this task, and is extensively used in research and industry. As with any method using noisy measurement data, the modal parameter estimates are afflicted with uncertainty. However, their uncertainty quantification has been incomplete, in particular for the case of real-valued polynomial coefficients in the modelling of the frequency response functions (FRFs) in the pLSCF algorithm, and no expressions have been available for the covariance of participation vectors and mode shapes that are subsequently estimated with the least-squares frequency domain (LSFD) approach. This work closes these gaps. Uncertainty expressions for the modal parameters, including participation vectors and mode shapes, are derived and presented. It is shown how to estimate the covariance between different modal parameters, and a complete method is provided for modal parameter covariance estimation from pLSCF. The method is propagating the uncertainty of FRFs through the algorithm using first-order perturbation theory and the delta method. The method is validated via extensive Monte-Carlo simulations and the applicability is illustrated using a laboratory experiment. [34]

7.3.2 New joint estimation method for emissivity and temperature distribution based on a Kriged Marginalized Particle Filter : application to simulated infrared thermal image sequences

Participants: Thibaud Toullier, Jean Dumoulin, Laurent Mevel.

This work addresses the challenge of simultaneously estimating temperature and emissivity for infrared thermography in natural environment, aiming for near real-time performance. Existing methods, mainly in satellite observation field, rely on restrictive physical assumptions unsuitable for ground-based application context (Structures and Infrastructures monitoring). Other generic methods are nonetheless computationally intensive, making them impractical for real-time use. Our objective is to provide a method with effective realtime calculation performance while still giving results comparable to those reference methods under the same hypotheses, finally achieving both good accuracy and performance. The proposed method is based on a dynamical state-space modeling for the temperature, where the state vector is assumed to be split into a dynamic component for the temperature and a stationary component representing the emissivity. Then the dynamical component is estimated by a Kalman filter approach, whereas the parameterized model and the emissivity component are estimated through a particle filtering framework resulting in a bank of Kalman filters, also called marginalized particle filter. A spatial assumption of homogeneity for the temperature yields to the addition of a Kriging step to the Marginalized Particle Filter to overcome the ill-posed nature of the problem and to compute the necessary physical estimates in a reasonable amount of time while providing fair results compared to reference methods from the literature. A comparison with two state-of-the-art methods, MCMC and CMA-ES, is presented. The results indicate that the proposed method estimates the true value within a maximum deviation of 3K, similar to CMA-ES, while MCMC achieves a more accurate estimate with a maximum deviation of 0.5K. How- ever, the computational efficiency of the proposed method is significantly improved, reducing the processing time by seven orders of magnitude com- pared to MCMC and three orders of magnitude compared to CMA-ES. This remarkable efficiency highlights the method's feasibility for real-time monitoring of temperature and emissivity. [35]

7.3.3 Subspace-based wavenumber identification in periodic waveguides adapted to full-field vibration measurements

Participants: Alvaro Gavilán Rojas, Qinghua Zhang, Christophe Droz.

Identifying wave propagation properties in periodic media, such as composite or architected materials, is critical for characterizing complex structures experimentally. Subspace identification algorithms are commonly applied to Operational Modal Analysis (OMA) data in the time domain; here, the focus is on frequency-domain data collected from successive periodic unit cells in 1D-periodic waveguides. Instead of estimating modal parameters like natural frequencies, the aim is to determine the real and imaginary parts of the structural wavenumber, related to wavelength and spatial decay, as well as Bloch wave modes, which describe physical wave propagation such as torsion and compression. Recent advances in full-field vibration measurement techniques provide multiple measurement points per unit cell, allowing statistical mitigation of the limitations due to a small number of unit cells. This study proposes a subspace identification framework that leverages these dense measurements for improved wavenumber estimation. The approach is illustrated both through numerical simulations of a periodic beam and via experimental validation using optical deflectometry on periodic structures. By constructing a state-space representation derived from a wave-based finite element model, the method enhances the accuracy of wavenumber identification within each unit cell, offering a practical tool for characterizing periodic or architected materials. [46, 58]

7.3.4 Subspace System Identification with Unknown Disturbance Rejection

Participants: Qinghua Zhang.

System identification usually assumes that the considered system is driven by known inputs and/or stationary random noises. This work considers the case involving unknown inputs, which are arbitrary disturbances. A typical example is a mechanical structure naturally excited by wind, which changes direction from time to time. To address such disturbances, subspace methods for system identification will incorporate techniques of unknown input observers, which are state estimators with the ability to reject arbitrary unknown disturbances, provided a mathematical model of the system under consideration is available. Simulation results are reported to illustrate the proposed method for system identification while rejecting unknown disturbances. [57]

7.4 Joint data/model analysis

7.4.1 Physics-Informed Neural Networks for Structural Health Monitoring

Participants: Nikhil Mahar, Laurent Mevel.

Structural Health Monitoring (SHM) is crucial for ensuring the safety and durability of engineering structures. Physics-Informed Neural Networks (PINNs) provide a promising approach by combining data-driven models with physical knowledge, bridging the gap between purely model-based and purely data-driven methods. The works presented here explore complementary PINN-based strategies for SHM, focusing on inverse estimation, scalability, and robustness to unknown inputs.

An attention-augmented Long Short-Term Memory network (Pi-Attn-LSTM) is introduced for inverse parameter estimation without requiring complete state measurements. By integrating a temporal attention mechanism in an encoder-decoder setup, the network adaptively focuses on critical features in sequential data, improving accuracy in dynamic environments. Validation on multi-degree-of-freedom numerical simulations and a scaled aluminium frame demonstrates faster convergence and superior robustness compared to a conventional Pi-LSTM, enabling reliable identification of localized structural degradation. [27]

A parallel PINN framework addresses computational efficiency and scalability by decomposing high-dimensional structural systems into coupled lower-dimensional subproblems, one per degree of freedom, while maintaining global consistency through shared matrices. This approach supports efficient state and parameter estimation for both linear and nonlinear systems under harmonic and real earthquake excitations. Experimental validation on a scaled shear frame confirms robustness under sparse data, high noise, and varying system complexity. [26]

An input-robust LSTM (rPi-LSTM) integrates an output-injection strategy with physics-informed modeling to estimate both system states and spatial health parameters in the presence of unknown or unmeasured input forces, such as wind or variable loads. By preserving temporal dependencies while complying with system physics, the framework demonstrates strong robustness to unknown inputs, noise, and data sparsity. Validation on numerical simulations and laboratory-scale experiments highlights its practical potential for real-world SHM applications. [28]

A complementary approach combines Stochastic System Identification (SSI) with Physics-Informed Neural Networks (SSI-Pi-LSTM) for joint input-state-parameter estimation. SSI uses statistical and subspace-based techniques to estimate state-space matrices and dominant modal parameters from structural response data. Incorporating these parameters into the PINN framework reduces computation time and improves accuracy, enabling efficient and robust parameter identification for complex structural systems. [49]

7.4.2 Mitigating high dimensionality in damage identification for plate-like structures through substructuring with interacting filtering-based approaches

Participants: Shereena OA, Laurent Mevel.

High-dimensional plate-like structures, such as aircraft wings, building floors, or wind turbine blades, require early detection of damage to prevent sudden catastrophic failures. Traditional structural health monitoring methods rely on dense instrumentation and high-dimensional support models parameterized with damage attributes, which can be computationally expensive and costly to implement. This work introduces a substructuring approach combined with a robust Interacting Particle Kalman filter (IPEnKF) framework, enabling health estimation on manageable subdomains independently of the rest of the structure. The process model incorporates output injection to achieve robustness against unknown boundary forces on the substructures, while stage-wise monitoring reduces the required sensor coverage. Validation was performed through numerical simulations and experiments on a scaled trapezoidal Mindlin plate representing the NASA CRM wing. The subdomain approach reduced sensor requirements by 60% while maintaining 95% accuracy in damage detection and assessment. Computational costs were also significantly lowered, as each substructure is monitored independently. The method demonstrated high reliability with minimal false alarms, highlighting both the robustness of the IPEnKF algorithm and the critical role of strategic sensor placement in effective damage identification. [32]

7.4.3 Bayesian Filtering Approaches for SHM with Sparse Instrumentation exploiting time-lagged measurements

Participants: Shereena OA, Laurent Mevel.

Model-based strategies for Structural Health Monitoring (SHM) often rely on comprehensive system models and extensive instrumentation, which can be computationally and financially demanding. Bayesian filtering techniques provide a framework for estimating unobserved structural states and health parameters from available measurements. However, sparse instrumentation can limit observability, potentially leading to unrealistic or non-physical estimates.

To address this challenge, a time-lagged virtual sensor approach is introduced, leveraging delay-embedded measurement models based on Taken's theorem. By constructing virtual sensors from time-delayed measurements, the dimensionality of the measurement vector is enhanced, improving state observability. This method is integrated within a Bayesian filtering framework using an interacting particle-Kalman filter (IPKF), termed VS-IPKF. Unlike conventional spatial virtual sensors, which rely on model-based predictions at unmeasured locations, this approach uses actual measurements to generate virtual data, improving fidelity and reliability. Numerical validation on cantilever beam models and experimental tests demonstrate significant improvements in state and joint state-parameter estimation, especially under sparse instrumentation conditions. [33]

Building on this concept, the measurement model is further enhanced for accurate mode shape reconstruction by embedding time-lagged measurement layers. The Interacting Particle Kalman Filter (IPKF) updates the model in the time domain, allowing for refined system matrices and more precise mode shapes. This method addresses challenges such as non-collocated or insufficient instrumentation, data loss, and dependence on Finite Element Method-based expansions. Numerical experiments on a simply supported beam under ambient vibration highlight the method's improved accuracy and computational efficiency compared to traditional approaches. [56]

Extending these ideas, a novel lagged estimation framework in the modal domain combines time-lagged embeddings with reduced-order modeling for computational efficiency. Structural dynamics are characterized by mode shapes and natural frequencies modulated with location-specific health variables, forming a simplified state-space model. Integrated into a Bayesian filtering framework, this approach achieves precise state estimation even for sparsely monitored or complex time-varying systems. Observability analysis informs sensor allocation, and tests on linear time-invariant systems show that the method reduces sensor requirements while maintaining accuracy, demonstrating its potential for advanced SHM and parameter estimation. [53]

7.4.4 Identification and monitoring of stochastic linear subsystems with unknown local nonlinearities via output injection

Participants: Neha Aswal, Adrien Mélot, Laurent Mevel, Qinghua Zhang.

Most civil and mechanical structures exhibit nonlinear stochastic behaviour, which is difficult to model accurately, but necessary for conventional model-based structural health monitoring techniques. Although various methods have been developed to estimate nonlinear systems, they require information about the external excitation and are susceptible to sensor noise and modelling inaccuracies. This knowledge is challenging to acquire in practice. Hence, this work presents a novel nonlinearity model-agnostic approach to detect damage in mechanical systems with localized nonlinearities. The proposed method utilises output injection to reject the unknown nonlinearities as if they were unknown disturbances. By applying an existing disturbance rejection technique, the need for a priori knowledge about the functional form of nonlinearities is avoided. Besides, a switching strategy is employed to determine the most probable location of the nonlinearities, thereby eliminating the need for a priori knowledge about their location. The method makes use of interacting particle Kalman filter, where the particle filter estimates the parameters (health indices) in order to detect possible damage while the Kalman filter simultaneously estimates the states. The efficiency of the proposed method is demonstrated with the help of numerical experiments on a spring-mass-damper oscillator chain with attached localized nonlinearity. The proposed approach is further validated against experimental data of jointed beams. [19]

7.4.5 Damage detection and localization method for wind turbine rotor based on Operational Modal Analysis and anisotropy tracking

Participants: Ambroise Cadoret, Laurent Mevel.

Subspace-based damage detection methods are widely used for civil engineering structures modeled as linear time-invariant systems. For operating wind turbines modeled as linear time-periodic systems, these methods cannot be theoretically used, due to the inherent assumptions associated with these methods in the context of linear time-invariant systems. Based on a model approximation of time-periodic systems as time-invariant ones, these methods can still be applied and adapted to perform change detection for time-periodic systems, through a Gaussian residual built upon damage sensitive parameters coming from the identified modal parameters. The proposed method is tested and validated on data simulated with an aero-servo-elastic model of an operating wind turbine, with the detection of local stiffness reductions on a blade and the localization of the damaged blade. Furthermore, two selections of sensors are tested, to evaluate the impact of the sensor choice on the performance of the detection and localization methods. [20]

7.4.6 Model Updating of Rotating Wind Turbines Using Operational Modal Analysis and Floquet Mode Decomposition

Participants: Nina Delette, Laurent Mevel.

The structural complexity of modern wind turbines, combined with numerous uncertain or unknown parameters, presents significant challenges for accurate predictive modeling. Model updating, which refines numerical model parameters using measurement data, offers a means to mitigate these discrepancies. While extensively applied to stationary structures, its extension to rotating wind turbines remains limited, as their time-periodic dynamics violate key assumptions underlying conventional methods. This study develops a numerical framework for model updating of rotating wind turbines based on an equivalent Linear Time-Invariant (LTI) approximation, derived through a Fourier decomposition of the system's Floquet modes. A simplified 5 Degrees of Freedom (DoF) turbine model is employed to evaluate the effectiveness of a deterministic model updating strategy leveraging this approximation. Synthetic vibration data, generated from the model using a predefined parameter set, serve as reference measurements for assessing parameter recovery accuracy. Modal features extracted via Operational Modal Analysis (OMA) are used to construct the cost function that quantifies discrepancies between predicted and observed modes. The results underscore the potential of equivalent LTI representations in facilitating model updating for rotating systems, as they effectively capture the modal characteristics identified via OMA. This study establishes a foundation for extending this methodology to more complex, industrial-scale wind turbine models, provided that the computational cost of model evaluation remains manageable. [39, 40]

7.4.7 An indirect data-driven model-updating framework to estimate soil–pile interaction parameters using output-only data

Participants: Michael Doehler.

A data-driven model updating framework is developed to estimate the operational parameters of a laterally-impacted pile. The goal is to facilitate the estimation of soil-pile interaction parameters such as the mobilized mass and stiffness, as well as geometrical data such as embedded pile length, using output-only information. Accurate knowledge of mass, stiffness, and pile embedded length is essential for understanding foundation behavior when developing digital-twin models of structures for the purpose of damage detection. The method first employs subspace identification to determine modal parameters and quantifies their uncertainties using output-only data. The covariance matrix adaptation evolution strategy (CMA-ES), a stochastic evolutionary algorithm, is subsequently used to update the model. The effectiveness of the approach is demonstrated through its application to numerical models in this work, to quantify errors, and subsequently to data from a documented full-scale field test of a pile subjected to an impact load. The work underscores the potential of statistical updating in advancing the accuracy and reliability of soil-structure interaction parameter estimation for systems where only output data might exist. [23]

7.4.8 Subspace-Based Noise Covariance Estimation for Bayesian Filters in SHM

Participants: Michael Doehler, Neha Aswal, Laurent Mevel, Qinghua Zhang.

The performance of Kalman and Bayesian filters in state and parameter estimation critically depends on accurate knowledge of process and measurement noise covariances. In practice, these covariances are often unknown and heuristically tuned, which can be cumbersome and may not yield optimal results. Optimization-based or matrix inversion methods exist but are computationally demanding and potentially numerically unstable.

A subspace-based identification approach provides an efficient method to estimate the covariance of potentially correlated process and measurement noises, particularly in virtual sensing applications. Virtual sensors are used to reconstruct system responses at unmeasured locations, enabling the monitoring of structural states where physical instrumentation is limited. The subspace-based method outperforms traditional autocovariance least-squares schemes and provides reliable initial covariance estimates even in the presence of model errors. Laboratory experiments demonstrate that predictions at sensor locations not used in the identification procedure closely match actual measurements, validating both the covariance estimation and the virtual sensing framework.

Integrating the estimated covariances into Bayesian filtering strategies enhances structural health monitoring (SHM) performance. Comparative studies show that using subspace-based covariance estimates improves the accuracy and efficiency of state and damage estimation under conditions of sensor noise, modeling errors, and unmeasured inputs, highlighting the value of combining virtual sensing with robust noise covariance identification. [22, 37]

8 Bilateral contracts and grants with industry

8.1 Bilateral contracts with industry

SNCF: Hot boxes detection

Participants: Jean Dumoulin, Thibaud Toullier, Boualem Merainani.

The main strategic issue is the maintenance in operational condition of the Hot Box Detectors (DBC). The removal of the DBC from the track is part of Tech4Rail's ambition: reducing equipment to the track. The innovation aimed at in this project is to study and develop a measurement solution to be deployed at the edge of a lane out of danger zone and independent of track equipment. Among the scientific obstacles identified are the following three:

- the behavior of the measurement system in deteriorated meteorological conditions in a real site,
- the design and implementation of an automated prototype for in-situ deployment (connection to an existing announcement system, hardware packaging of the system, study and design of a scalable software solution allowing pre-processing data),
- the development of automatic processing tools for the analysis of massive data generated by in-situ measurement systems.

Siemens: Proof of concept monitoring coupled with prediction model for de-icing metro lane surface

Participants: Jean Dumoulin, Thibaud Toullier, Mathias Malandain.

A proof of concept study aims at combining real site monitoring solutions with adjoint state FE thermal model approach to predict optimal heating required to preserve surface from icing in winter conditions. Furthermore, we introduced in our prediction model connection with in-line weather forecast provided by Meteo France Geoservice at different time horizons and spatial scales. Total amount: 124 k€.

CETIM: fiber optic monitoring

Participants: Xavier Chapeleau.

CETIM is conducting fatigue testing on a tank until it bursts, using existing fiber optic sensors based on Bragg gratings for deformation measurement points. This expertise project aims to enhance this setup with additional fiber optic sensors for distributed deformation measurements in a testing campaign, with the goal to compare the effectiveness of these two monitoring technologies. Total amount: 20k€, until 2025.

Hottinger Brüel & Kjær (HBK): uncertainty quantification for frequency-domain modal analysis

Participants: Michael Doehler, Mikkel Steffensen.

In the context of the PhD of Mikkel Steffensen (DTU Denmark / HBK), a research collaboration with HBK has started on developping methods for uncertainty quantification for input/output frequency-domain modal analysis. Mikkel has spent one month at Inria in 2024 for joint work on the subject. The developed codes have been transferred to HBK's equipment software in 2025.

9 Partnerships and cooperations

9.1 International initiatives

9.1.1 Inria associate team not involved in an IIL or an international program

PhyNET

Title: Integrating eigenspace and physical space information via PINN architecture towards stochastic distance-based damage detection

Duration: 2024 -> pres.

Coordinator: Subhamoy Sen

Partners:

- IIT Mandi (India)

Inria contact: Laurent Mevel

Summary: Structural Health Monitoring (SHM) is an essential process that involves real-time monitoring of the physical condition of a mechanical structure in the presence of environmental variations. This monitoring relies on data collection through sensors and the utilization of reference models that describe the structure in its initial state. This coupling between sensors and numerical models proves to be extremely challenging, primarily due to the significant disparity between the limited number of available sensors and the high complexity and dimensionality of the models required for accurate monitoring. The fondamental objective of this research project is to improve state-of-the-art SHM strategies coupling experimental data with numerical modelling by combining them with physics-informed neural networks (PINNs). The numerical model should assist the PINN in enhancing limited real-world data with model-generated, damage-sensitive physical features. This integration aims at generalizing SHM methods while making them adaptable to various dynamic conditions and improve their robustness to noise, sensor defects, and model errors.

9.1.2 Participation in other International Programs

Collaboration with Imperial College London

Participants: Adrien Melot.

A. Melot collaborates with Imperial College London on the topic of structural optimisation and identification for nonlinear vibrations.

Collaboration with IIT Mandi

Participants: Laurent Mevel, Christophe Droz, Adrien Melot.

L. Mevel has been directing the thesis of Neha Aswal (defense 10/2023) with S. Sen at IIT Mandi, who has joint the I4S team as a postdoc with the BIENVENUE program (12/2023-11/2025). L. Mevel is co-directing PhD candidate Nikhil Mahar at IIT Mandi since 09/2023. Shereena OA and Nikhil Maher from IIT Mandi have visited the I4S team in May 2025, and Sheerena OA has made another visit in October 2025.

Collaboration with Université de Sherbrooke

Participants: Christophe Droz, Qinghua Zhang.

C. Droz and Q. Zhang are directing the thesis of Alvaro Gavilan-Rojas with O. Robin at Université de Sherbrooke. The subject is the propagation of guided waves in periodic structures.

9.2 International research visitors

9.2.1 Visits of international scientists

Other international visits to the team

Shereena OA

Status: Postdoc

Institution of origin: IIT Mandi

Country: India

Dates: 04/05–24/05/2025; 02/11–16/11/2025

Context of the visit: associated team PhyNet

Mobility program/type of mobility: Inria Associated Team; mobility grant of French Institute in India

Nikhil Mahar

Status: PhD student

Institution of origin: IIT Mandi

Country: India

Dates: 04/05–24/05/2025

Context of the visit: associated team PhyNet

Mobility program/type of mobility: Inria Associated Team

Lisa Schwegmann

Status: PhD student

Institution of origin: University of Rostock

Country: Germany

Dates: 18/08–03/10/2025

Context of the visit: collaboration on vibration-based damage loclaization with Michael Doehler

Mobility program/type of mobility: research stay funded by University of Rostock

Martina Vitali

Status: PhD student

Institution of origin: Politecnico Milano

Country: Italy

Dates: 01/03–31/08/2025

Context of the visit: vibration-based damage analysis of bridges

Mobility program/type of mobility: research stay Italian PhD program

W.K. Chiu

Status: Professor

Institution of origin: Monash University

Country: Australia

Dates: 07/07/2025

Context of the visit: Scientific visit with Vincent Le Cam around SHM topic

Mobility program/type of mobility:

9.2.2 Visits to international teams

Research stays abroad

Michael Doehler

Visited institution: Aalborg University, Learning and Decisions Lab

Country: Denmark

Dates: 06/02–13/02/2025

Context of the visit: collaboration on uncertainty quantification, invited seminar

Mobility program/type of mobility: research stay

Romain Noel

Visited institution: Université Jan Evangelista Purkyně, chemistry department

Country: Czech Republic

Dates: 20/10–24/10/2025

Context of the visit: collaboration on computational fluid dynamic, invited seminar

Mobility program/type of mobility: Hubert Curien Partnerships (PHC) Barrande

9.3 European initiatives

9.3.1 Horizon Europe

BRIGHTER BRIGHTER project on cordis.europa.eu

Title: Breakthrough in micro-bolometer imaging

Duration: From December 1, 2022 to November 30, 2026

Partners:

- INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET AUTOMATIQUE (INRIA), France
- MER MEC FRANCE (INNOTECH), France
- XENICS NV (XENICS), Belgium
- SENSIA SOLUTIONS SL (SENSIA), Spain
- MACQ SA (MACQ), Belgium
- COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (CEA), France
- CHAUVIN ARNOUX, France
- BIGTRI BILISIM ANONIM SIRKETI, Türkiye
- ARCELIK A.S. (ARCELIK), Türkiye
- LYNRED (LYNRED), France
- UNIVERSITE GUSTAVE EIFFEL, France
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS), France
- THIMONNIER SAS, France
- DOCAPESCA - PORTOS E LOTAS SA, Portugal
- MARMARA UNIVERSITY (MarUn), Türkiye
- INOV INSTITUTO DE ENGENHARIA DE SISTEMAS E COMPUTADORES INOVACAO (INOV), Portugal

Inria contact: Laurent Mevel

Coordinator: LYNRED, Xavier Lucquiault

Summary: Micro-bolometer sensors are compact, light, low power, reliable and affordable infrared imaging components. They are ahead of the cooled infrared sensors for these criteria but lag behind them in terms of performance:

- Existing micro-bolometer technologies have thermal time constants around 10 msec. This is more than 10 times that of cooled detectors.

- Moreover, there is no multispectral micro-bolometer sensor available today for applications such as absolute thermography and optical gas imaging.

BRIGHTER will develop 2 new classes of micro-bolometer solutions to reduce the performance gap with their cooled counterparts:

- Fast thermal micro-bolometer imaging solutions with time constant in the 2.5 to 5 msec range, that is to say 2 to 4 times faster than that of today's micro-bolometer technologies. Read out integrated circuits able to operate up to 500 frames per seconds will also be investigated.

- Multi-spectral micro-bolometer solutions with at least access at the pixel level to 2 different wavelengths in the range 7 to 12 µm.

The developments will focus on pixel technology, Read Out Integrated Circuit, low power edge image signal processing electronic, optics, and image treatment algorithms. All stakeholders of the value chain are involved: academics, RTO, micro-bolometer manufacturer, algorithm developers, camera integrators and end users. They will collaborate to define the best trade-offs for all use-cases.

The 2 new classes of products that will spring from BRIGHTER will generate concrete benefits. They will make it possible to save on material and energy in the manufacturing sector, perform efficient and affordable monitoring of infrastructures and trains, contribute to autonomous vehicles sensor suite, decrease the road casualties among Vulnerable Road Users, better control gas emission in cities and industrial areas. These new usages served by the European industry will allow Europe to increase its market share in the infrared imaging industry.

USES2

Participants: Vincent Le Cam, Romain Noel.

USES2 project on cordis.europa.eu

Title: USES of novel Ultrasonic and Seismic Embedded Sensors for the non-destructive evaluation and structural health monitoring of critical infrastructure and human-built objects

Duration: 2023–2027

Partners:

- UGE
- Universidad Politécnica de Madrid (UPM)
- COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (CEA)
- FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV (IZFP)
- BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG (BAM)
- ISAMGEO ITALIA S.R.L. (Isamgeo)
- UNIVERSITE LIBRE DE BRUXELLES (ULB)
- AIRBUS DEFENCE AND SPACE SA (AIRBUS)
- ZENSOR (Zensor)
- UNIVERSITY OF BRISTOL (UBRI)

Inria contact: Vincent Le Cam

Coordinator: Université Gustave Eiffel, Odile Abraham

Summary: Infrastructure makes up the arteries of modern society, providing people, organisations with all necessities – from utilities to housing and transport. However, its maintainance can be difficult. While non-destructive evaluation is the process currently being used, it is disruptive to infrastructure. An interesting possibility is to use condition-based structural health monitoring (SHM) with sensors. However, these sensors currently provide local information making it inefficient for the size and complexity of infrastructure. The EU-funded USES2 project aims to develop an alternative by bringing together new sensor technologies, improved processing tools and full-mechanical-waveform-based imaging, as well, as training researchers to efficiently utilise these tools. This will allow for efficient larger-scale infrastructure structural health monitoring, essential for their everyday use.

9.4 National initiatives

ANR PRC SWEAT-City

Participants: Romain Noel, Jean Dumoulin.

- Duration: 2024 – 2028
- Budget: 409 k€
- Title: Simulation of Water Evaporation within Artificial ground for Thermo-regulation of the City
- Abstract: The global warming and the more extreme events related implies that cities will be concerned by Urban Heat Island (UHI) effect more often and more intensively. Pavements cover between 30% and 40% of city areas and have a strong effect on the UHI. Studies are showing that two major phenomena can be used and then must be studied to reduce the effect of pavements on UHI: The albedo and the evaporation of water. The increase in albedo has a beneficial effect on the surface temperature of pavements but increases radiation on the vertical surfaces of the city. The present proposal focuses on the effect of water evaporation on UHI. Research on that topic is increasing in the recent years, and only few papers are available on the numerical simulation. However, the evaporation of porous media is a complex phenomenon by its geometry, its interactions between the matrix and fluids, the phase change etc. This complexity leads to macroscopic models with numerous parameters that are hard to obtain experimentally and to optimize. The aim of the project is to develop a heat and mass numerical model that considers evaporation in a construction material. The model is based on a multiscale approach combining the ability of Lattice Bolzman Method at the pore scale and Finite Element at the macro scale. Experiments will be carried out at different scales to validate the modelings. Finally experiments in simulated real life situation within the Sense City facility will be performed and simulated in order to validate the models.

ANR JCJC Archi-Noise

Participants: Christophe Droz.

- Duration: 2024 – 2028
- Budget: 286 k€
- Title: Architected materials with meso-scale interactions for Noise and vibration control
- Abstract: Noise, vibration, and harshness (NVH) impact multiple industries, affecting health, system longevity, and sustainability. Despite advances in NVH mitigation materials, performance gains are plateauing due to constraints like cost, compactness, adaptability, and structural integrity. ArchiNoise seeks to redefine material design by exploring architected meta-structures at meso- and macro-scales, surpassing traditional vibro-acoustic limits. It will adapt nano-scale physics and electromagnetism concepts to structural engineering, creating scattering effects akin to Bragg and locally resonant bandgaps, but independent of periodic unit-cell dimensions or oscillator mass. These novel waveguiding phenomena will target broadband NVH control. ArchiNoise will develop theoretical, computational, and phenomenological tools to design and optimize these materials. By integrating enriched continuum theories, vibroacoustics, inverse wave-based identification, and lattice-based periodic modeling, it will pioneer lightweight NVH solutions.

ANR France 2030 ExcellenceS City-FAB / CD 92

Participants: Jean Dumoulin, Thibaud Toullier, Mathias Malandain.

- Duration: 2024 – 2028
- Partners: CD 92, UGE laboratories
- Budget: 600 k€, 80 k€ for the team
- Title: Analysis of uses, and study of comfort and urban atmosphere on an avenue scale
- Abstract: The objective is to anticipate and adapt road redevelopment projects by aiming at better sharing of mobility spaces, making travel safer and enhancing the environment. These objectives meet the issues of sustainable cities and territories. This project focuses on the environmental effects of developments, in particular concerning thermal comfort, air quality and acoustic comfort. Our contribution to this project focuses on in-situ monitoring and data-driven studies.

ANR SCaNING

Participants: Vincent Le Cam.

- Duration: 2021 – 2025
- Partners: UGE (Coordinator), Université de Toulouse, Aix-Marseille Université, Université de Bordeaux, Andra, EDF
- Inria contact: Vincent Le Cam
- Abstract: Using embedded sensors which will provide information similar to that used in NDE while allowing to continuously evaluate performance indicators (compressive strength and Young's modulus) and the concrete conditions (porosity and water content) to improve indicator reliability and optimize diagnosis and communicating sensors through fully autonomous, low-power networks makes it possible to consider systems with low installation and operation costs. The project is lead by MAST LAMES laboratory of UGE. The instrumentation part is ensured by I4S.

ANR Convinces

Participants: Jean Dumoulin, Romain Noël.

- Duration: 11/2021 – 10/2025
- Partners: Univ. Lorraine (coordinator), CERTES (UPEC), Univ. Strasbourg, UGE, Cerema.
- Abstract: The ANR project CONVINCES is investigating the influence of convection in suspensions of micro-encapsulated phase change material (mPCM) in urban civil engineering applications. This project will include LBM (Lattice Boltzmann Method) and DEM (Discrete Element Method) in multi-scale simulations plus series of experiments at different scales to study the thermal impact of such mPCM suspensions in porous media. The final objective is the thermal regulation of pavements.

ANR RESBIOBAT

Participants: Jean Dumoulin.

- Duration: 01/2022 – 12/2025
- Partners: UGE (coordinator), CERTES (UPEC), LNE, CSTB, Cerema, Themacs Ingénierie.
- Abstract: The ANR project RESBIOBAT addresses energy and environmental issues. Major advances are expected in the building sector. Reliable in-situ thermal characterization of buildings before and after a renovation action are required. Moreover, construction must be more "sustainable", notably by using bio-sourced materials and raw earth. In this project, we propose an inter-disciplinary technical solution combining modeling, simulations and measurements for a better in-situ evaluation of the energy performances of conventional and sustainable walls. The identification of the thermal characteristics will be performed by an inverse method combining a hygro-thermal model solved in real time by a "reduced bases" technique and sensors selected by "optimal experimental design". After a robustness study via virtual tests, a prototype will be realized and tested on real walls in laboratory and in the Equipment of Excellence Sense-City.

PIA4: MINERVE

Participants: Vincent Le Cam.

- Duration: 2022–2027
- 22 partners, coordinator: SNCF. Budget: 40 M€, 743 k€ for the team
- Title: Méthodes et outils pour la collaboration sectorielle et la continuité numérique sur le cycle de vie (MINERVE)
- Abstract: The six main objectives of the MINERVE project are: - Develop design and construction methods and tools using effective BIM approaches for each business - Anticipate and optimize the construction phase, based on sustainable BIM (digital continuity, frugality of models) - Developing digital twins (exploring the potential of AI for decision support), using opportunities with regard to biodiversity and the environment - Use the digital twin to improve resilience to climate change - Develop an industrializable, standardized and shared vision of interfaces ensuring digital continuity via the BIM model on all phases - Build a collaborative ecosystem around the modeling of linear and particularly railway infrastructure

  The team participates with BIM and monitoring of railway structures by modeling vibrations, defining original ways of operational monitoring including fiber optic sensors.

PIA4: DIAM

Participants: Vincent Le Cam.

- Duration: 2022–2026
- Partners: STIMIO (coordinator), SNIC, UGE. Budget: 3 M€, 693 k€ for the team.
- Abstract: In this project, new ways to diagnose infrastructure deterioration are identified through the use of innovative instrumentation and by merging different data sources. With focus on railway monitoring, the goal is online diagnosis communication of critical trackside elements, and to enrich trackside elements with augmented infrastructure monitoring systems. New algorithms and models for predictive maintenance are developed.

ANR France2030 Sci-ty Geronimo

Participants: Vincent Le Cam, Arthur Bouche, Adji Toure.

- Duration: 10/2025-09/2027
- Abstract: This project is a maturation project aimed at advancing Acoustic Emission technologies and associated know-how to a higher TRL. The objective is to develop off-the-shelf, fully synchronized wireless sensor nodes capable of running Structural Health Monitoring (SHM) algorithms in situ and in real time, such as Time Difference of Arrival (TDOA) algorithms.

ANR France2030 Sci-ty OBLiX

Participants: Romain Noel.

- Duration: 02/2025-01/2026
- Abstract: The OBLiX pre-maturation project aims at its extension and development. The main objective is to address the real need for tools enabling structural health monitoring (SHM) for sustainable, resilient, and safe cities. Currently, the field lacks generic, flexible, and efficient solutions for connecting sensors to physical and mathematical models. OBLiX, stands out for its ability to combine genericity, flexibility, lightweight design, and efficiency. It offers an approach better suited to SHM and embedded electronics. OBLiX's innovative nature lies in its combination of functionalities and its ability to combine highly heterogeneous models. Its development is part of the National Acceleration Strategy for Sustainable Cities and Innovative Buildings, thus contributing to the emergence of a sustainable construction culture and the creation of a community of SHM experts.

ANR France2030 Sci-ty TAPAS

Participants: Thibaud Toullier, Arthur Bouche.

- Duration: 05/2025-04/2026
- Abstract: The TAPAS software (Tracking, Acquisition, Processing, Archiving & Storage) addresses the growing needs of instrumentation projects, which play a key role in the development of tomorrow's smart and connected cities. Designed to manage complex projects and supervise large-scale sensor networks, the development of TAPAS ensures the collection, storage, visualization, archiving, and control of the generated data.

  A dedicated programming interface enables seamless integration into domain-specific applications, while an intuitive user interface allows users to visualize and manage projects as well as control data sharing. TAPAS therefore supports structural health monitoring and energy optimization of infrastructures, contributing to more sustainable, resilient, and innovative cities.

  Finally, through the integration of computational models, TAPAS paves the way for the deployment and operation of digital twins dedicated to the real-time monitoring, control, and optimization of infrastructures.

CETIM

Participants: Michael Doehler, Xavier Chapeleau.

- Duration: 09/2024–08/2025
- Partners: CETIM, I4S, UGE/MAST-SMC. Budget: 100 k€
- Abstract: This research collaboration funded by CETIM aims at developing a thesis project focused on data fusion and AI using data from SHM sensors to create predictive models for fatigue damage (initiation and propagation of cracks) in welded structures. This preliminary study focuses on evaluating SHM sensors and the processing and fusion of data related to the considered use case.

CETIM

Participants: Michael Doehler, Christophe Droz.

- Duration: 10/2025–09/2028
- Partners: CETIM, I4S. Budget: 240 k€
- Abstract: Following the previous research collaboration with CETIM, a PhD project has been launched within the strategic partnership between Inria and CETIM. The PhD of Hovanes Boksyan on Digital twins for monitoring welded mechanical components is funded within CETIM's Digital Twin program.

AID

Participants: Christophe Droz, Michael Doehler.

- Duration: 10/2025–09/2028
- Partners: DGA TT, Université Angers, I4S.
- Abstract: This project aims to improve vibration analysis methods used to assess the reliability and durability of complex systems - particularly military vehicles and their onboard equipment - under realistic operating conditions. Building on the NF X50-144 standard, the work seeks to replace generic test procedures with more customized, data-driven approaches using AI techniques to analyse vibration profiles for fatigue prediction.

CEA

Participants: Romain Noel.

- Partners: CEA/DM2S/STMF.
- Abstract: Within the Inria/CEA collaborative framework, I4S and the LMSF started to work together on CFD methods. This collaboration led to a first M2 internship and the collaboration continues through the PhD project of Clément Bardet (2024–2027) on the use of thermo-chemical potential in LBM.

IFPEN

Participants: Laurent Mevel.

Collaboration with IFPEN leading to the thesis of A. Cadoret on applying OMA techniques on wind turbines, and a new PhD project has started with PhD candidate N. Delette (2023–2026).

AEx - Fluidonics

Participants: Christophe Droz, Romain Noel.

- Duration: 05/2025–10/2028
- Abstract: This project explores seismic barrier concepts relying on fluid sloshing. The objective is to optimize the internal flow turbulence as well as the tank's structural design to combine dissipation phenomena with interference of seismic waves. The M2 internship of Methmika Athulkotte (05-10/2025) was dedicated to the project, and PhD student Louis Ramseyer started in 11/2025.

ANR ASTRID HYDRAVIB

Participants: Boris Lossouarn.

- Duration: 09/2023–08/2026
- Partners: Cnam (coordinator), Arts et Métiers Lille, École navale
- Title: Piezoelectric damping for mitigation of flow-induced vibrations
- Abstract: Unlike electromagnetic waves, underwater acoustic waves propagate with very low attenuation and can be measured more than a hundred kilometers away. Acoustic noise comes from various sources including propeller cavitation, hydroacoustic phenomena and vibration of structural components. The HYDRAVIB project aims to reduce the vibration-induced noise under hydrodynamic flow by proposing piezoelectric damping techniques intended for the mitigation of structural resonances. These techniques will also contribute to the increase in the lifespan of the blades, hydrofoils or fins, by reducing fatigue in a vibrating environment.

10 Dissemination

10.1 Promoting scientific activities

10.1.1 Scientific events: organisation

General chair, scientific chair

- Michael Doehler
  - General chair of IOMAC 2025, Rennes, 20-23/05/2025
- Jean Dumoulin
  - Chair of the scientific day on Inrared Thermography for the French Society of Thermal Science (Paris, Fiap Jean Monet, 16th October 2025)

Member of the organizing committees

- Vincent Le Cam
  - Organization of SHM@COFREND day, Grenoble, 19-20/03/2025
  - Part of the organization of IWSHM at Standord, USA, 9-11/09/2025
  - Part of the organization of the SHM days of Gustave Eiffel University Marne la Vallée, France, 5-6/11/2025
- Christophe Droz, Laurent Mevel, Adrien Melot, Alvaro Gavilan Rojas, Gunther Tessier
  - Organizing committee of IOMAC 2025, Rennes, 20-23/05/2025

Session organization

- Jean Dumoulin
  - co-chair of session GI5.1 | Urban Geophysics at EGU GA 2025
- Adrien Mélot
  - Organization and co-chair of session: "S8: Modeling and computational methods for physical model-based identification" at IOMAC 2025
- Christophe Droz
  - Organization and co-chair of session: "S8: Modeling and computational methods for physical model-based identification" and chair of the Industrial Keynotes Session at IOMAC 2025

10.1.2 Scientific events: selection

Chair of conference program committees

- Vincent Le Cam
  - head and general secretary of the EWSHM scientific committee
- Jean Dumoulin
  - vice chairman of QIRT steering committee since 2024

Member of the conference program committees

- Jean Dumoulin
  - member of the scientific committee of the GI Division (Geosciences Instrumentation and Data Systems) of EGU (European Geosciences Union) for infrastructure instrumentation and monitoring since 2013 and GI Division sub-Program Committee member since 2020
  - member of the scientific committee of QIRT (quantitative Infrared Thermography) since 2014
- Qinghua Zhang
  - member of the 6th International Conference on Control and Fault-Tolerant Systems (SysTol 2025) scientific committee
  - member of IFAC Technical Committee on Modelling, Identification and Signal Processing (TC 1.1)
  - member of IFAC Technical Committee on Adaptive and Learning Systems (TC 1.2)
  - member of IFAC Technical Committee on Fault Detection, Supervision and Safety of Technical Processes (TC 6.4)

- Laurent Mevel
  - member of the EWSHM scientific committee
  - member of the IOMAC scientific committee
- Vincent Le Cam
  - member of the IWSHM scientific committee
  - member of SHM@COFREND scientific committee
- Michael Doehler
  - member of IFAC Technical Committee on Modelling, Identification, and Signal Processing (TC 1.1) since 2017
  - member of the IOMAC scientific committee since 2018
  - member of the SHM@COFREND scientific committee since 2021
  - member of the EWSHM scientific committee since 2022
  - member of EVACES 2025 scientific committee and award committee

Reviewer

- Michael Doehler was reviewer for EVACES 2025.
- Jean Dumoulin was reviewer for QIRT ASIA 2025, EGU 2025.
- Vincent Baltazart was reviewer for IOMAC 2025.
- Qinghua Zhang was reviewer for CDC 2025, SysTol 2025.
- Adrien Mélot was reviewer for NeurIPS AI4Science Workshop, NODYCON 2025, IFAC Symposium on Robotics, IFAC Symposium on Mechatronic Systems, ASME Turbomachinery Technical Conference & Exposition, IOMAC 2025.
- Christophe Droz was reviewer for IOMAC 2025.
- Romain Noel was reviewer for GRETSI 2025.

10.1.3 Journal

Member of the editorial boards

- Jean Dumoulin is member of the editorial board of the journal Quantitative Infrared Thermography, and Executive Editor for the journal Geoscientific Instrumentation, Methods and Data Systems.
- Laurent Mevel is member of the editorial board of the journal of Mechanical Systems and Signal Processing.

Reviewer - reviewing activities

- Christophe Droz was reviewer for Nonlinear Dynamics, Advances in Engineering Software, Physics of Fluids, Mechanical Systems and Signal Processing, Journal of Sound and Vibration, Wave Motion, European Journal of Mechanics - A/Solids.
- Laurent Mevel was reviewer for Mechanical Systems and Signal Processing and Engineering Structures.
- Michael Doehler was reviewer for Mechanical Systems and Signal Processing, Journal of Sound and Vibration, Data-Centric Engineering
- Jean Dumoulin was reviewer for Building and Environment, SPIE Optical Engineering, GI Journal (EGU), QIRT Journal.

- Romain Noel was reviewer for Journal Computational Particle Mechanics.
- Xavier Chapeleau was reviewer for the journals Journal of Civil Structural Health Monitroing, Engineering Structures, Measurement, Sensors and Actuators A Physical.
- Vincent Baltazart was reviewer for NDT&E, MSSP, Measurement, Applied Sciences, Optik, IEEE Trans. Intelligent Transportation System, Engineering Structures, Automation in Construction.
- Qinghua Zhang was reviewer for IEEE Transactions on Automatic Control, Automatica, Mechanical Systems and Signal Processing.
- Adrien Mélot was reviewer for Nonlinear Dynamics, Mechanical Systems and Signal Processing, Journal of Sound and Vibration, Communications in Nonlinear Science and Numerical Simulation, International Journal of Dynamics and Control, Journal of Nonlinear Mathematical Physics.
- Boris Lossouarn was reviewer for Mechanical Systems and Signal Processing and Nonlinear Dynamics.

10.1.4 Invited talks

- Christophe Droz
  - "Modélisation des structures périodiques: Applications à la non-localité, non-linéarité, l'identification et la réduction de modèles". Institut Polytechnique de Paris, UMA, POEMS, France, 11/12/2025.
  - "Reduced frequency-driven Bloch Wave Decomposition for Harmonic Analysis of Finite Periodic Structures". 7th International Conference on Phononic Crystals/Metamaterials, Phonon Transport, Topological Phononics, Seoul, Korea, 09/06/2025.
  - "Dynamics of Periodic Structures: modeling, identification and applications". ISAE-Supmeca, VAST-FM, France, 06/02/2025.
- Vincent Le Cam
  - introduction keynote on SHM development in France at the 8th SHM@COFREND day in Grenoble, 19/03/2025
- Michael Doehler
  - “Statistical uncertainties and change detectability in vibration-based structural monitoring”, invited seminar, Aalborg University, Denmark, 11/02/2025
- Jean Dumoulin
  - “Ultra Time Domain Infrared Thermography in ground based outdoor monitoring: outcomes and perspectives”, QIRT ASIA 2025, HARBIN, China, 14-18 July 2025.
- Boualem Merainani
  - “Détection et suivi de boites d'essieux par thermographie infrarouge ”, Journée d'étude de la Société Française de Thermique (SFT) sur la Thermographie Infrarouge, 16 octobre 2025, FIAP, Paris.
- Thibaud Toullier
  - “DAM2 - A Scalable and Compliant Solution for Managing enriched Infrared images as FAIR Research Data ”, Journée d'étude de la Société Française de Thermique (SFT) sur la Thermographie Infrarouge, 16 octobre 2025, FIAP, Paris.
- Adrien Mélot
  - "An Overview of Deep Learning Paradigms for Mechanical Engineering", Lyon, France, 06/11/2025.

- Romain Noel
  - "The LBM use for fluid dynamics in granular media", invited seminar at Université Jan Evangelista Purkyně, Czech Republic, 10/2025
  - "Phase change for thermoregulation of porous media", invited talk at the compagny Dotblock, 11/2025, France.

10.1.5 Leadership within the scientific community

- Vincent Le Cam
  - co-chair of SHM@COFREND: this activity branch of the COFREND (French Confederation for Non-destructive Testing) aims at uniting the national SHM community from academia and industry, and to promote and standardize the SHM sector in France.
  - member of the scientific council of WEN (West Electronic Network) since 2014, which is a cluster of about 200 companies, academics and research laboratories active in electronics
- Michael Doehler
  - co-leader of the working group “GT SHM Data” within SHM@COFREND. The GT focuses on scientific issues, technical challenges and standards of the SHM sector related to handling and processing of structural monitoring data. The GT involves around 50 people from academia and industry in France.

10.1.6 Scientific expertise

- Christophe Droz was expert evaluator for the French National Research Agency (ANR) and for the Campus Polytechnique Grants of Université Le Havre Normandie.
- Adrien Mélot was scientific expert for the French National Research Agency (ANR)

10.1.7 Research administration

- Laurent Mevel
  - deputy head of science of Inria Rennes
  - member of Commisision d’Evaluation at Inria
  - member of the jury CESAAR at Ministère de la Transition Écologique et Solidaire
- Vincent Le Cam
  - deputy co-head of COSYS department at Université Gustave Eiffel
- Jean Dumoulin
  - member of Commisision d’Evaluation des chercheurs du Ministère de la Transition Ecologique (MTE)
- Xavier Chapeleau
  - member of Commisision d’Evaluation des chercheurs du Ministère de la Transition Ecologique (MTE)

10.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

10.2.1 Teaching

- Jean Dumoulin
  - Licence Professionnelle TAM (Techniques Avancées en Maintenance): thermographie infrarouge active, 30h, Université Paris-Est Créteil (UPEC), France
  - Master 2 ITII, BTP, module Maintenance et réhabilitation des ouvrages, Transferts thermiques dans les Structures : Des principes physiques à l'application sur site réel, 12 h, Ecole Centrale de Nantes (ECN), France.
- Vincent Le Cam
  - Master Electrical Engineering (GEII), 3h CM in M1, 4h CM in M2 on electronic systems and Structural Monitoring, Université Bretagne Sud, Lorient, France
  - M2 ENSIM Le Mans, 5h CM (monitoring des structures par capteurs sans fils)
  - EC Nantes, 4h CM + 32h TP (electronique embarquée, Linux et drivers)
  - Ecole d'Ingénieur Builders, 10h CM, Caen
- Xavier Chapeleau
  - M1 ITI, fibre-optique, 8h, IUT Nantes
  - "Monitoring and auscultation : Optical fiber sensors", Infrastar Training School, November 2025
- Romain Noel
  - École des Mines de Saint-Étienne, Master 2, Fluid Mechanics Applications: Plenary conference (2h)
  - École des Mines de Saint-Étienne, Master 1, Advanced Fluid Mecanics: Lectures (6h) + practical lessons (6h)
  - École Centrale de Nantes, Master 2, Data Signal and Image: Lectures (4h) + practical lessons (4h)
  - École Polytech' Nantes, Master 1, Probabilty and Statistics: Lectures (12h) + practical lessons (3h)
- Christophe Droz
  - MSc 1, Modélisation en Action, Dpt. Mathématiques, Université de Rennes (50h)
  - MSc 2, Contrôle non destructif et identification, Dpt. Sciences pour la matière, Université de Rennes (20h)
- Alvaro Gavilan Rojas
  - Master 2, Mécanique et Matériaux, Contrôle non destructif et identification, 1.5h CM + 5h TD, Université de Rennes
- Lucas Rouhi
  - L1 Biologie, Environnement et Chimie du Vivant (BECV), 57h TD en mathématiques, 6h TP initiation Python, Université de Rennes
- Nicolas Madinier
  - STP03 MECA, mécanique du solide, 22h TD, INSA Rennes
- Boris Lossouarn
  - From september 2025 : International Master (M2), Smart structures - Piezoelectric shunt damping, Cnam, Paris (15h)

10.2.2 Supervision

PhD students

- Clément Rigal, *Modélisation multi-échelle d'écoulements convectifs avec des matériaux à changement de phase micro-encapsulés à travers un milieu poreux*, Y. Hoarau, D. Funfschilling, Romain Noel, A. Chouippe, Ecole doctorale MSTII, defense 07/2025.

- Mira Kabbara, *Modélisation et caractérisation de capteurs à fibre optique continus*, Qinghua Zhang, F. Bourquin, Xavier Chapeleau, Ecole doctorale Matisse, defense 12/2025.

- Arij Khaled Fawaz, *Etude de l'évolution des lois cohésives d'interface en mode II pour un assemblage collé sous charge en milieu marin*, S. Chataigner, E. Lepretre, Xavier Chapeleau, Ecole doctorale SIS, defense 11/2025.

- Alvaro Gavilan Rojas, *Reduced order models for non-destructive evaluation of periodic structures*, Christophe Droz, Qinghua Zhang and O. Robin, Ecole doctorale Matisse, defense 12/2025.

- Nina Delette, *Development of data-driven approaches for physics-informed wind-turbine digital twins and application to real-world data*, Laurent Mevel, E. Denimal and J.-L. Pfister, Ecole doctorale Matisse, since 11/2023.

- Nikhil Mahar, *Machine learning techniques for SHM*, Laurent Mevel and S. Sen, IIT Mandi, since 09/2023.

- Marios Kaminiotis, *Embedded self-powered sensor devices for passive monitoring of composite components*, Vincent Le Cam, Romain Noel and Bastien Chapuis, Ecole docotrale STIC, since 01/2024.

- Zakariae Moutaouakil, *Estimating/Modelling the statistical degradation laws of the secondary road network from video-based pavement monitoring devices*, Laurent Mevel, Ph. Foucher, and Vincent Baltazart, within the scope of the ROAD-AI project with Cerema, since 10/2024.

- Clément Bardet, *Simulation of multiphase flow coupled with temperature using Lattice Boltzmann Method and chemical potential*, Laurent Mevel and Romain Noel, Ecole doctorale Matisse, since 10/2024.

- Lucas Rouhi, *Non-local architected meta-structures for lightweight vibro-acoustic design*, Christophe Droz, Qinghua Zhang, Ecole Doctorale Matisse, since 09/2024.

- Benoit Senard, *An algebraic framework for phononic systems modelling*, Christophe Droz, Michael Doehler, Ecole Doctorale Matisse, since 10/2024.

- Hamado Ouedraogo, *Numerical Mutli-scale Simulation of Evaporation and Imbibition of Building Porous Material*, Romain Noel and Christian La Borderie, École doctorale sciences exactes et leurs applications, since 10/2025.

- Hovanes Boksyan, *Digital twin for the monitoring of welded components*, Michael Doehler, Christophe Droz, Fan Zhang and Philippe Amazouga (CETIM), Ecole Doctorale Matisse, since 10/2025.

- Pierre Lague, *Artificial Intelligence for Structural Resilience Optimization under Severe Vibratory Stress*, Christophe Droz, Michael Doehler, Nicolas Gutowski (Université Angers), Sébastien Aubin (DGA TT), Ecole Doctorale Matisse, since 10/2025

- Antoine Barré, *Taking into account metrology drift in long term wireless sensor networks applied to SHM*, Vincent Le Cam, Julien Le Scornec, Laurent Mevel, David Betaille (UGE), UGE, since 11/2025

- Louis Ramseyer, *Designing next-generation seismic metamaterials with hybrid particle- and wave-based simulations*, Christophe Droz, Romain Noel, Adrien Mélot, Ecole Doctorale Matisse, since 11/2025

- Valentin Mouton, *Reductionist Deep Learning for Mechanical Engineering*, Adrien Mélot, Emmanuel Rigaud and Joel Perret-Liaudet, Ecole Centrale Lyon, since 2023
- Lisa Schwegmann, *Vibration-based damage localization on civil structures*, Michael Doehler and Volkmar Zabel, University of Rostock, since 2025
- Matthieu Marion, *Vibration analysis of metallic structures filled with damping materials*, Boris Lossouarn, Lucie Rouleau and Jean-François Deü, Conservatoire national des arts et métiers and Naval Group (Cifre), since 2022
- Arthur Haudeville, *Vibration mitigation of hydrofoils using piezoelectric shunt damping*, ANR ASTRID HYDRAVIB, Boris Lossouarn and Xavier Amandolèse, Conservatoire national des arts et métiers, Christophe Giraud-Audine and Olivier Thomas, Arts et Métiers Lille, since 2023
- Pierre Flament, *Vibration damping of multiple resonances through interconnected piezoelectric networks*, Boris Lossouarn and Jean-François Deü, Conservatoire national des arts et métiers and Naval Group (Cifre-Défense), since 2023
- Murilo Freitas, *The Use of Climate and Meteorogical Parameters to Model thermomecanical Pavement Ageing*, Romain Noel, Mohamed Belmokhter and Pierre Hornych, EDSIS, since 2024
- Salahedine Djaoui, *Mechanical & Thermal Optimization of a Solar Energy Harvesting Road*, Romain Noel, Éric Gennesseaux, Thierry Sedran, Florian Huchet and Emmanuel Chailleux, EDSIS, since 2024

Postdocs and research engineers

- Boualem Merainani, postdoc funded by SNCF then european Project KDT JU BRIGHTER, supervised by Jean Dumoulin, 09/2021-12/2025.
- Neha Aswal, postdoc funded by BIENVENÜE, supervised by Qinghua Zhang and Laurent Mevel, 12/2023-11/2025.
- O A Shereena, postdoc at IIT Mandi, co-supervised by Laurent Mevel, since 09/2023.
- Julian Legendre, postdoc at Inria, co-supervised by Laurent Mevel, Jean Dumoulin and Thibaud Toullier, 09/2024–08/2025.
- Nicolas Madinier, postdoc in ANR JCJC at Inria, supervised by Christophe Droz, 09/2025-02/2027.
- Antoine Barré, research engineer, DIAM, supervised by Vincent Le Cam, 11/2024–10/2025.
- Nathanaël Gey, Junior Research Engineer in CityFAB CD92 project since 11/2024, then Sci-ty TAPAS, co-supervised by Thibaud Toullier and Jean Dumoulin, then since 04/2025 by Thibaud Toullier and Arthur Bouché.
- Jean-Noël Coueron, engineer, in OBLiX-premat, supervised by Romain Noel, 02/2025-01/2026.
- Adji Touré, engineer and co-head of Geronimo-EA project, supervised by Vincent Le Cam, 10/2025-09/2027
- Antoine Morvan, postdoc in ANR ASTRID HYDRAVIB at École navale and Cnam, co-supervised by Boris Lossouarn, 09/2024-03/2026

Internships

- Nino Landormy (IMT Atlantique), Digitalizing an NDT measurement process for civil engineering operators, apprenticeship supervised by Vincent Baltazart, Romain Noel and Thibaud Toullier, 10/2023–09/2026.
- Adji Toure (EC Nantes), embedded software for GERONIMO system, apprenticeship supervised by Arthur Bouche, 09/2022–08/2025.
- Coralie Thuillier (ENS), Plateforme remote HPC pour la modélisation et la visualisation de simulations dynamiques, 09/2025-04/2026.
- Omar Laouiti, M2 (Univ Strasbourg), Flow in a porous medium with a thermal mPCM concentration, supervised by Romain Noel, 02-08/2025
- Hamza Saissi (ENSIMAG), Study of a water tank subjected to stochastic excitation, M1 internship, supervised by Romain Noel and Christophe Droz, 05-09/2025
- Methmika Athulkotte (EPF Engineering School), Modelling Seismic Surface Wave Scattering through Subsurface Heterogeneities: Development of Simulation Code, M2 internship, supervised by Christophe Droz and Romain Noel, 05-10/2025
- Nino Dos Santos (UBS Lorient), Energy performance study of a hybrid solar road demonstrator in a controlled and then natural environment, M1, supervised by Jean Dumoulin, 04-06/2025
- Lucas Czamanski Meireles (Ecole Centrale Lyon), Weather forecasts for boundary conditions of a finite element model of an energy-harvesting pavement, supervised by Jean Dumoulin and Thibaud Toullier, 04-10/2025
- Lucas Doula (UBS Lorient), GPSd Porting to PEGASE4 and Synchronization Accuracy Qualification, M1, supervised by Vincent Le Cam, 04-08/2025
- Maxence Bouleau (Polytech Nantes), Deployment of a Novel UWB Wireless Communication Using the Spark Development Kit for the DIAM Use Case, supervised by Vincent Le Cam, 06-08/2025
- Hovanes Boksyan (INP Grenoble), Data Processing and Fusion for Fatigue-Induced Damage Detection, M2 internship, supervised by Michael Doehler and Xavier Chapeleau, 02-07/2025
- Mathis Creff (Univ Rennes), Sous-structuration dynamique pour l'assemblage de cellules unitaires, M1 internship, supervised by Christophe Droz, 05-07/2025
- Valentine Nayl (Univ Rennes), Échantillonnage adaptatif pour la construction d'un modèle de substitution, M1 internship, supervised by Christophe Droz, 05-07/2025
- Arthur Kittler (Univ Strasbourg), Étude et mise en œuvre de méthodes de détection automatique par machine learning de désordres sur des images de chaussée, M2 internship, supervised by Philippe Foucher (Cerema), Alain Hebting (Cerema) and Fabien Menant (UGE), 02-08/2025

10.2.3 Juries

- Michael Doehler
  - External reviewer PhD Brandon O'Connell, "Novel Probabilistic and Bayesian Approaches to Uncertainty Quantification for Operational Modal Analysis". Sheffield University, UK, 02/2025.
  - External reviewer PhD Armin Hermes, "High fidelity aeroelastic stability analysis of complex blades in 3D flow". Technical University of Denmark, Denmark, 03/2025.
- Christophe Droz
  - PhD external reviewer F. Qu "Frequency dependent and parametric reduced order models for NVH simulation of metamaterial structures", KU Leuven, Belgium, 12/2025.

  - CSI member of PhD candidate K. Mouffok "Optimization and Management of Event Logging in Distributed Embedded Networks", INSA Rennes.
  - CSI member of PhD candidate N. Klaimi "Sparse model-based deep learning for massive MIMO". IETR Rennes.

- Laurent Mevel
  - PhD Reviewer - Université de Lille. ELIE ROUPHAEL, "Towards Stochastic Realization Theory for Linear Switched Models". Defense October 24 2025.

- Chapeleau Xavier
  - CSI member of PhD candidate: Bzeih Rayan, 'Development of methods for analyzing fiber optic measurement data to determine deformation and damage to underground concrete structures.', Nantes Université.

- Romain Noel
  - CSI member of PhD candidate: Khac Minh Tam Truong, 'Optimization of Phylogenetic Compression Algorithms', Inria Rennes.
  - CSI member of PhD candidate: Mahmoud Assaf, 'Numerical modeling and optimization of two-phase flows with change of state', Polytech'Nantes.
  - CSI member of PhD candidate Badr Eddine Hamaid, 'Decarbonizing cities on the climate change context: application to the tertiary building', Univ. Eiffel.

10.2.4 Educational and pedagogical outreach

- Christophe Droz was involved in Chiche!: a scientific mediation program promoting scientific careers to high-school students (Lycée Sévigné).

10.3 Popularization

10.3.1 Specific official responsibilities in science outreach structures

- Christophe Droz is co-organizator of the Sci-Rennes seminar series at the Inria center of the University of Rennes (since Sep. 2022).

10.3.2 Participation in Live events

- Boris Lossouarn actively contributed to the first Carnot ARTS "Tech Show" on September 30, 2025 by presenting a vibration damping demonstrator for hydrofoils, developed within the SMARTFOIL project (2019–2022, co-funded by Carnot ARTS). The proposed experimental setup integrates piezoelectric material to mitigate flow-induced vibrations. This live presentation illustrated the scientific foundations and technological bricks enabling next-generation smart structures for vibration analysis and control.

10.3.3 Others science outreach relevant activities

- Vincent Le Cam, Jean Dumoulin, Vincent Baltazart, Romain Noel, Xavier Chapeleau, Thibaud Toullier, Arthur Bouché have participated in the Journées Portes Ouvertes on the UGE campus in Nantes, with several demonstrators.

- Vincent Le Cam organizes the stay of high school students for internships on the UGE campus in Nantes.

11 Scientific production

11.1 Major publications

[1] B. Delyon and Q. Zhang. 'On the Optimality of the Kitanidis Filter for State Estimation Rejecting Unknown Inputs'. In: *Automatica* 132 (13th July 2021), article n°109793. DOI: 10.1016/j.automatica.2021.109793. URL: https://inria.hal.science/hal-03041232.

[2] M. Döhler, L. Mevel and Q. Zhang. 'Fault Detection, Isolation and Quantification from Gaussian Residuals with Application to Structural Damage Diagnosis'. In: *Annual Reviews in Control* 42 (2016), pp. 244–256. DOI: 10.1016/j.arcontrol.2016.08.002. URL: https://inria.hal.science/hal-01376804.

[3] A. Gavilán Rojas, Q. Zhang and C. Droz. 'A computationally efficient k(ω)-spectral form for partial dispersion analyses within the wave finite element framework'. In: *Journal of Sound and Vibration* 593 (22nd Dec. 2024), p. 118652. DOI: 10.1016/j.jsv.2024.118652. URL: https://hal.science/hal-04750240.

[4] S. Gres, M. Döhler and L. Mevel. 'Statistical model-based optimization for damage extent quantification'. In: *Mechanical Systems and Signal Processing* 160 (Nov. 2021), p. 107894. DOI: 10.1016/j.ymssp.2021.107894. URL: https://inria.hal.science/hal-03468260.

[5] S. Greś, M. Döhler, V. Dertimanis and E. Chatzi. 'Subspace-based noise covariance estimation for Kalman filter in virtual sensing applications'. In: *Mechanical Systems and Signal Processing* 222 (Jan. 2025), p. 111772. DOI: 10.1016/j.ymssp.2024.111772. URL: https://hal.science/hal-04767232.

[6] E. Kuncham, N. Aswal, S. Sen and L. Mevel. 'Bayesian monitoring of substructures under unknown interface assumption'. In: *Mechanical Systems and Signal Processing* 193 (June 2023), p. 110269. DOI: 10.1016/j.ymssp.2023.110269. URL: https://inria.hal.science/hal-04148639.

[7] J. Le Scornec, B. Guiffard, R. Seveno, V. Le Cam and S. Ginestar. 'Self-powered communicating wireless sensor with flexible aero-piezoelectric energy harvester'. In: *Renewable Energy* 184 (Jan. 2022), pp. 551–563. DOI: 10.1016/j.renene.2021.11.113. URL: https://inria.hal.science/hal-03908995.

[8] N. Le Touz, T. Toullier and J. Dumoulin. 'Study of an optimal heating command law for structures with non-negligible thermal inertia in varying outdoor conditions'. In: *Smart Structures and Systems* 27.2 (2021), pp. 379–386. DOI: 10.12989/sss.2021.27.2.379. URL: https://hal.inria.fr/hal-03145348.

[9] Z. Luo, B. Merainani, V. Baltazart, Q. Zhang and M. Döhler. 'Subpixel motion estimation for video-based target-free vibration monitoring under complex environmental conditions'. In: *Mechanical Systems and Signal Processing* 226 (Mar. 2025), p. 112342. DOI: 10.1016/j.ymssp.2025.112342. URL: https://inria.hal.science/hal-04894400.

[10] P. Mellinger, M. Döhler and L. Mevel. 'Variance estimation of modal parameters from output-only and input/output subspace-based system identification'. In: *Journal of Sound and Vibration* 379 (6th June 2016), pp. 1–27. DOI: 10.1016/j.jsv.2016.05.037. URL: https://inria.hal.science/hal-01328435.

[11] A. Mendler, M. Döhler and C. U. Grosse. 'Predictive probability of detection curves based on data from undamaged structures'. In: *Structural Health Monitoring* 23.3 (2024), pp. 1725–1741. DOI: 10.1177/14759217231193088. URL: https://inria.hal.science/hal-04557859.

[12] B. Merainani, B. Xiong, V. Baltazart, M. Döhler, J. Dumoulin and Q. Zhang. 'Subspace-based modal identification and uncertainty quantification from video image flows'. In: *Journal of Sound and Vibration* 569 (Jan. 2024), p. 117957. DOI: 10.1016/j.jsv.2023.117957. URL: https://inria.hal.science/hal-04436527.

[13] R. Noël, F. Qin, L. Fei and J. Carmeliet. 'Adjustable surface tension independent of the collision operator for pseudo-potential lattice Boltzmann methods'. In: *Physical Review Fluids* 10.10 (7th Oct. 2025), p. 104901. DOI: 10.1103/lrz9-ll2v. URL: https://hal.science/hal-05375568.

[14] R. Noël, A. Renier-Robin and L. Navarro. 'Generalized Dithering using the Lattice Boltzmann Method'. In: *Signal, Image and Video Processing* 18.12 (20th Sept. 2024), pp. 8507–8523. DOI: 10.1007/s11760-024-03465-x. URL: https://hal.science/hal-04815444.

[15] D. Pallier, V. Le Cam and S. Pillement. 'Energy-efficient GPS synchronization for wireless nodes'. In: *IEEE Sensors Journal* 21.4 (15th Feb. 2021), pp. 5221–5229. DOI: 10.1109/JSEN.2020.3031350. URL: https://hal.science/hal-02968155.

[16] T. Toullier, J. Dumoulin and L. Mevel. 'New joint estimation method for emissivity and temperature distribution based on a Kriged Marginalized Particle Filter : application to simulated infrared thermal image sequences'. In: *Science of Remote Sensing* 11 (June 2025), p. 100209. DOI: 10.1016/j.srs.2025.100209. URL: https://inria.hal.science/hal-04966544.

[17] B. Zaparoli Cunha, C. Droz, A.-M. Zine, S. Foulard and M. Ichchou. 'A Review of Machine Learning Methods Applied to Structural Dynamics and Vibroacoustic'. In: *Mechanical Systems and Signal Processing* 200 (2023), p. 110535. DOI: 10.1016/j.ymssp.2023.110535. URL: https://hal.science/hal-03563614.

11.2 Publications of the year

International journals

[18] M. Al Bacha, M.-L. Nguyen, P. Hornych, O. Chupin, J. Blanc and X. Chapeleau. 'Full-scale experimental and numerical analysis of pavement surface layers responses to different loading conditions'. In: *Road Materials and Pavement Design* (17th Nov. 2025). DOI: 10.1080/14680629.2025.2584556. URL: https://hal.science/hal-05399021 (cit. on p. 16).

[19] N. Aswal, A. Mélot, L. Mevel and Q. Zhang. 'Identification and monitoring of stochastic linear subsystems with unknown local nonlinearities via output injection'. In: *Mechanical Systems and Signal Processing* 238 (1st Sept. 2025), p. 113239. DOI: 10.1016/j.ymssp.2025.113239. URL: https://inria.hal.science/hal-05229475 (cit. on p. 22).

[20] A. Cadoret, E. Denimal-Goy, J.-M. Leroy, J.-L. Pfister and L. Mevel. 'Damage detection and localization method for wind turbine rotor based on Operational Modal Analysis and anisotropy tracking'. In: *Mechanical Systems and Signal Processing* 224 (1st Feb. 2025), p. 111982. DOI: 10.1016/j.ymssp.2024.111982. URL: https://inria.hal.science/hal-04902642 (cit. on p. 22).

[21] N. Derrien, M. Lehujeur, X. Chapeleau, O. Durand, A. Gallet, N. Roussel, B. Yven and O. Abraham. 'Challenges of Embedding Fiber Bragg Grating Sensors in Castable Material : Influence of Material Shrinkage and Fiber Coatings on Ultrasonic Measurements'. In: *Sensors* 25.9 (23rd Apr. 2025), p. 2657. DOI: 10.3390/s25092657. URL: https://univ-eiffel.hal.science/hal-05045724 (cit. on p. 16).

[22] S. Greś, M. Döhler, V. Dertimanis and E. Chatzi. 'Subspace-based noise covariance estimation for Kalman filter in virtual sensing applications'. In: *Mechanical Systems and Signal Processing* 222 (Jan. 2025), p. 111772. DOI: 10.1016/j.ymssp.2024.111772. URL: https://hal.science/hal-04767232 (cit. on p. 24).

[23] A. Ioakim, S. Greś, M. Döhler, L. J. Prendergast and E. Chatzi. 'An indirect data-driven model-updating framework to estimate soil–pile interaction parameters using output-only data'. In: *Engineering Structures* 328 (Apr. 2025), p. 119699. DOI: 10.1016/j.engstruct.2025.119699. URL: https://inria.hal.science/hal-04902544 (cit. on p. 23).

[24] M. Kabbara, X. Chapeleau, Q. Zhang and F. Bourquin. 'Strain Transfer Model Assessment for Steel-Reinforced and Polymer-Coated Optical Fiber Cables Used as Distributed Strain Sensors'. In: *IEEE Sensors Letters* 9.8 (Aug. 2025), pp. 1–4. DOI: 10.1109/LSENS.2025.3589372. URL: https://inria.hal.science/hal-05367567 (cit. on p. 13).

[25] Z. Luo, B. Merainani, V. Baltazart, Q. Zhang and M. Döhler. 'Subpixel motion estimation for video-based target-free vibration monitoring under complex environmental conditions'. In: *Mechanical Systems and Signal Processing* 226 (Mar. 2025), p. 112342. DOI: 10.1016/j.ymssp.2025.112342. URL: https://inria.hal.science/hal-04894400 (cit. on p. 14).

[26] N. Mahar, S. Sen and L. Mevel. 'A parallel framework of physics-informed neural networks for model identification of linear and nonlinear systems'. In: *Structures* 79 (Sept. 2025), p. 109454. DOI: 10.1016/j.istruc.2025.109454. URL: https://inria.hal.science/hal-05140778 (cit. on p. 20).

[27] N. Mahar, S. Sen and L. Mevel. 'An Attention-Augmented Long Short-Term Memory Network for PINN-based Structural Health Monitoring'. In: *Engineering Structures* 340 (1st Oct. 2025), p. 120673. DOI: 10.1016/j.engstruct.2025.120673. URL: https://inria.hal.science/hal-05153432 (cit. on p. 20).

[28] N. Mahar, S. Sen and L. Mevel. 'Physics informed Long Short-Term Memory neural network for dual state-parameter estimation of linear dynamical systems robust to input forces'. In: *Mechanical Systems and Signal Processing* 236 (Aug. 2025), p. 113012. DOI: 10.1016/j.ymssp.2025.113012. URL: https://inria.hal.science/hal-05148812 (cit. on p. 21).

[29] V. Mahé, A. Mélot, B. Chouvion and C. Droz. 'Computing the dynamic response of periodic waveguides with nonlinear boundaries using the Wave Finite Element Method'. In: *Computers & Structures* (8th Apr. 2025). DOI: 10.1016/j.compstruc.2025.107778. URL: https://hal.science/hal-05037340 (cit. on p. 17).

[30] A. Mélot. 'Optimizing bifurcations and singularities for performance enhancement and mitigation of the adverse dynamics of nonlinear energy sinks'. In: *Nonlinear Dynamics* (6th Aug. 2025). DOI: 10.1007/s11071-025-11638-7. URL: https://hal.science/hal-05202603 (cit. on p. 16).

[31] R. Noël, F. Qin, L. Fei and J. Carmeliet. 'Adjustable surface tension independent of the collision operator for pseudo-potential lattice Boltzmann methods'. In: *Physical Review Fluids* 10.10 (7th Oct. 2025), p. 104901. DOI: 10.1103/lrz9-ll2v. URL: https://hal.science/hal-05375568 (cit. on p. 18).

[32] O. Shereena, E. Kuncham, P. C. Jain, L. Mevel and S. Sen. 'Mitigating high dimensionality in damage identification for plate-like structures through substructuring with interacting filtering-based approaches'. In: *Engineering Structures* 323.A (Jan. 2025), p. 119190. DOI: 10.1016/j.engstruct.2024.119190. URL: https://inria.hal.science/hal-04849379 (cit. on p. 21).

[33] O. Shereena, S. Sen and L. Mevel. 'Monitoring of sparsely observed structures by time-lagged Bayesian smoothing'. In: *Mechanical Systems and Signal Processing* 241 (Dec. 2025), p. 113493. DOI: 10.1016/j.ymssp.2025.113493. URL: https://inria.hal.science/hal-05335360 (cit. on p. 21).

[34] M. T. Steffensen, M. Döhler, D. Tcherniak and J. J. Thomsen. 'Variance estimation of modal parameters from the poly-reference least-squares complex frequency-domain algorithm'. In: *Mechanical Systems and Signal Processing* 223 (Jan. 2025), p. 111905. DOI: 10.1016/j.ymssp.2024.111905. URL: https://hal.science/hal-04767208 (cit. on p. 19).

[35] T. Toullier, J. Dumoulin and L. Mevel. 'New joint estimation method for emissivity and temperature distribution based on a Kriged Marginalized Particle Filter : application to simulated infrared thermal image sequences'. In: *Science of Remote Sensing* 11 (June 2025), p. 100209. DOI: 10.1016/j.srs.2025.100209. URL: https://inria.hal.science/hal-04966544 (cit. on p. 19).

Invited conferences

[36] C. Droz and A. C. Gavilan-Rojas. 'Reduced Frequency-driven Bloch Wave Decomposition for Harmonic Analysis of Finite Periodic Structures'. In: *PHONONICS 2025: 7th International Conference on Phononic Crystals/Metamaterials/Metasurfaces, Phonon Transport, and Topological Phononics*. Phononics 2025 - 7th International Conference on Phononic Crystals/Metamaterials/Metasurfaces, Phonon Transport, and Topological Phononics. Seoul, South Korea, 13th June 2025, pp. 58–59. URL: https://hal.science/hal-05224427 (cit. on p. 17).

International peer-reviewed conferences

[37] N. Aswal, S. Greś, L. Mevel and Q. Zhang. 'Improving Bayesian filters for structural health monitoring applications with subspace-based noise covariance estimates'. In: *IOMAC 2025 proceedings*. IOMAC 2025 - 11th International Operational Modal Analysis Conference. Rennes, France, 2025, pp. 1–8. URL: https://hal.science/hal-05232736 (cit. on p. 24).

[38] R. Brincker, C. Gentile, M. Aenlle, J. Bienert, C. Rainieri and M. Döhler. '20 Years of IOMAC'. In: IOMACS 2025 - 11th International Operational Modal Analysis Conference. Rennes, France, 20th May 2025. URL: https://hal.science/hal-05398602.

[39] N. Delette, E. Denimal Goy, J.-L. Pfister, R. El Amri and L. Mevel. 'Model Updating of Rotating Wind Turbines Using Operational Modal Analysis and Floquet Mode Decomposition'. In: IOMAC 2025 - 11th International Operational Modal Analysis Conference. Rennes, France, 20th May 2025, pp. 1–7. URL: https://hal.science/hal-05232742 (cit. on p. 23).

[40] N. Delette, J.-L. Pfister, E. Denimal Goy, M. R. El Amri and L. Mevel. 'Bayesian model updating of rotating wind turbines'. In: WESC 2025 - Wind Energy Science Conference. Nantes, France, 24th June 2025, pp. 1–3. URL: https://inria.hal.science/hal-05380846 (cit. on p. 23).

[41] E. Denimal Goy, Y. Shen, S. Fruchard, A. Mélot and L. Renson. 'Topology Optimization of Isolated Response Curves in 3D Geometrically-nonlinear Beam'. In: *Nonlinear Structures & Systems, Vol. 1 - Proceedings of the 43rd IMAC, A Conference and Exposition on Structural Dynamics 2025*. IMAC 2025 - 43rd Conference and Exposition on Structural Dynamics. Orlando, United States: River Publishers, 7th Aug. 2025, pp. 81–92. DOI: 10.13052/97887-438-0146-7. URL: https://inria.hal.science/hal-05380323 (cit. on p. 18).

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[43] J. Dumoulin, D. Vizzari, L. C. Meireles, T. Toullier, J.-L. Manceau, E. Gennesseaux, S. Lavaud, E. Chailleux and T. Sedran. 'Outdoor Hybrid Solar Road Demonstrator Monitoring Using Infrared Thermography with Embedded Local Probes for Energy Harvesting Performance Evaluation'. In: *AITA 2025*. AITA 2025 - 18th International Workshop on Advanced Infrared Technology and Applications. Proceedings. Kobe, Japan: MDPI, 12th Sept. 2025, p. 37. DOI: 10.3390/proceedings2025129037. URL: https://inria.hal.science/hal-05356950 (cit. on p. 15).

[44] A. Fawaz, E. Lepretre, X. Chapeleau and S. Chataigner. 'Evaluation of a new adhesively bonded sample configuration adapted for ELS test and creep frame setups'. In: CICE 2025 - 12th International Conference on FRP Composites in Civil Engineering. Lisbon, Portugal, 2025. URL: https://hal.science/hal-05398814 (cit. on p. 16).

[45] M. Fodda, S. Chataigner, L. Battais, X. Chapeleau, M. Quiertant, A. Rolland and K. Benzarti. 'Experimental study on the bond behaviour between thermoplastic GFRP rebars and concrete'. In: JNC 2025 - Journées Nationales sur les Composites. Gif-sur-Yvette, France, 2025, pp. 1–6. URL: https://hal.science/hal-05360117 (cit. on p. 16).

[46] A. Gavilán Rojas, Q. Zhang, O. Robin and C. Droz. 'Subspace-based wavenumber identification in periodic waveguides adapted to full-field vibration measurements'. In: IOMAC 2025 - 11th International Operational Modal Analysis Conference. Rennes, France, 2025, pp. 1–7. URL: https://hal.science/hal-05204511 (cit. on p. 20).

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[48] V. Le Cam, A. Bouché, L. Lemarchand, A. Toure, A. Barre and L. Doula. 'PEGASE4 : a generic board for embedded SHM applications'. In: *IWSHM Proceedings 2025,* IWSHM 2025 - International Workshop on Structural Health Monitoring. IWSHM 2025 Proceedings. Palo Alto (Stanford), United States: Destech Publications, Inc., 11th Sept. 2025, pp. 534–542. URL: https://univ-eiffel.hal.science/hal-05399014 (cit. on p. 15).

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[51] B. Merainani, T. Toullier and J. Dumoulin. 'Comparative study of image quality acquired on a new portable dynamic laboratory test bench using two thermal time constant uncooled IRFPA microbolometric camera'. In: QIRT Asia 2025 - 5th Quantitative InfraRed Thermography Conference Asia. Harbin, China, 2025. URL: https://inria.hal.science/hal-05357087 (cit. on p. 15).

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