Ph.D. thesis subject

Data-driven non-linear structural identification

Deadline for application: 11 May 2025.
Starting date of the thesis: 1 October 2025.
Gross salary : 2300 euros
Disciplines: Mechanics, Civil engineering, Dynamics of structures, Informatics/Machine learning.
Keywords: Identification, nonlinear dynamics, temporal series of data, machine learning.
Co-directors of the thesis:

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Context

Structures, such as highway bridges, are subjected to dynamic loads and varied environmental conditions, which can lead to defects or degradations over time. These degradations, often invisible to the naked eye, can affect the safety, performance and durability of the structure. To this end, their early detections can prevent catastrophic failures. In this context, structural health monitoring through early defect characterization is a crucial area of infrastructure management [1, 2]. This monitoring mainly relies on the interpretation of variations in certain physical and/or mechanical parameters of the system --using linear and nonlinear dynamics techniques--, to link them to the health status of the structures [3].

One of the promising approaches for damage detection, which is based on data-driven models and not physical-driven models of the structure under normal conditions [4], relies on the measurement of vibrations of the structural elements by sensors such as accelerometers. These sensors, collect time series of data that reflect the dynamic state of the structure under the effect of external loads, climatic conditions and vibrations due to traffic. However, these time series often contain a large amount of complex information, and their analyses to accurately detect and to locate defects [5] (such as cracks, deformations or weakening of materials) is a major challenge.

Proposed research subject

The objective of this thesis is to develop innovative methods to characterize, to locate and to assess the severity of defects in civil engineering structures [6,7], by analyzing time series of data acquired by sensors [8]. In detail, it will involve identifying nonlinear properties of structural systems [9] --such as hysteresis responses of structural elements, nonlinear relationships of frequency responses and nonlinear distributions of stress fields-- by exploiting advanced data analysis techniques (denoising, filtering, classification) and machine learning [10]. The aim is to create a real-time monitoring system for structures capable of providing early warnings and recommendations for targeted maintenance interventions, thus improving the safety and durability of equipment.

References

[1] A. Bernard-Gély, F. Ricard, “Développement des capacités de réalisation de la restauration des ouvrages d’art routiers”, CG de l'env. et du dév. durable (CGEDD), 2021. 190 p.

[2] K. Gkoumas et al, “Indirect Structural Health Monitoring (iSHM) Of Transport Infrastructure in the Digital Age: MITICA Workshop Report”, European Union, JRC131885, KJ-04-23-036-EN-N, 2023.

[3] Y. Rossi *et al.*, “A New Paradigm for Structural Characterization, including Rotational Measurements at a Single Site”, Bull. Seismol. Soc. Am., 113: 2249–2274, 2023.

[4] A. Ture Savadkoohi *et al.*, “Finite element model updating of a semi-rigid moment resisting structure”, Struct. Control Health Monit., 18, 149-168, 2011.

[6] J. Liu *et al.* “Diagnosis algorithms for indirect structural health monitoring of a bridge model via dimensionality reduction”, Mech. Syst. Signal Proces.s, 136, 106454, 2020.

[7] L. Sun *et al.*, “Review of Bridge Structural Health Monitoring Aided by Big Data and AI: From Condition Assessment to Damage Detection”, J. Struct. Eng., 146(5):04020073, 2020.
[8] H. Li, S. Derrode, and W. Pieczynski, “Adaptive On-line Lower Limb Locomotion Activity Recognition Using Semi-Markov Model and Single Wearable Inertial Sensor”, Sensors, Vol. 19(19), 4242, 2019.
[9] K. Worden and P. Green, “A machine learning approach to nonlinear modal analysis”, Mech. Syst. Signal Process., 84, 34–53, 2017.
[10] O. Avci *et al.*, “A review of vibration-based damage detection in civil structures: From traditional methods to ML and DL applications,” Mech. Syst. Signal Process., 147, p. 107077, 2021.

Candidate profile

Candidates must hold a Master's degree (Master 2) in Computer Science and/or Signal Processing, or an engineering degree with one of these specializations. They should demonstrate a strong interest in Mechanics and/or Civil Engineering. Additionally, they must be fully autonomous in programming (Python/Matlab). He/she must be able to demonstrate autonomy, analytical skills, ease in oral and written communication and teamwork skills.

To apply, please send your CV, a cover letter and your master's transcripts, in a single PDF document, to the two email addresses indicated in the header, before the deadline.

Recruitment process: By the deadline, a shortlist of candidates will be invited to an audition by videoconference and will be ranked.

The laboratories and doctorate school

The PhD thesis will be carried out in the LTDS laboratory in the site ENTPE (3 rue Maurice Audin, 69518 Vaulx-en-Velin Cedex, France), under supervision of A. Ture Savadkoohi and S. Derrode.
Registration of the thesis will take place within doctorate school “ED MEGA (ED 162)” - Mécanique, Énergétique, Génie Civil et Acoustique.
This registration requires an accreditation phase which can take up to 2 months.
The thesis grant is part of the « Bouquet de thèses 2025 » of « Collège d’Ingénierie Lyon Saint-Étienne et de l’Université Jean Monnet de Saint-Étienne (*see below for details*).

Bouquet de thèses 2025

The doctoral thesis described below is part of a series of theses designed to build a multidisciplinary scientific approach to the societal challenge of a "responsible digital society", and more specifically, the specific theme of "Data and AI in a sustainable and responsible approach", identified as a priority issue by the 4 institutions of the Lyon Saint-Etienne Engineering College (Centrale Lyon, ENTPE, INSA Lyon, Mines Saint-Étienne) and by the Université Jean Monnet Saint-Étienne, which are providing financial support for the theses making up this 2025 package.

The 2025 theses package includes 6 theses covering different facets of data science and artificial intelligence, addressing the following questions:

- Monitoring crystallization processes using AI-assisted acoustic emission
- AI-assisted design of biodegradable and/or biosourced biopolymers for the sustainable protection of agricultural crops
- Machine learning methods for urban microclimate prediction
- Data-driven non-linear structure identification
- Inference and explicability in confidential mode: towards self-diagnosis via images
- Towards certification of vibration monitoring with explanatory AI

These theses involve a total of 16 supervisors from 11 laboratories on the Lyon Saint-Etienne site (Centre d'Innovation en Télécommunications et Intégration, Centre SPIN - Génie des Procédés, Ingénierie des Matériaux Polymères, Biologie Fonctionnelle, Insectes et Interactions, Institut Camille Jordan, Laboratoire de Mécanique des Fluides et d'Acoustique, Laboratoire de Tribologie et Dynamique des Systèmes, Laboratoire d'InfoRmatique en Image et Systèmes d'information, Laboratoire Hubert Curien, Laboratoire Vibrations Acoustique, Matériaux : Ingénierie & Science) of which the 5 funding institutions are supervisors. The 6 PhD students recruited under this package will be enrolled in 3 Doctoral Schools on the site: MEGA, EDML, SIS.

The teams (doctoral students and their supervisors) involved in these 6 theses form a multi-disciplinary scientific community: regular exchanges between these teams will take place throughout the 3 years of the doctoral pathway, notably in the form of joint seminars to develop the multi-disciplinary systems approach specific to the bouquet and enrich the teams' disciplinary skills in a spirit of sharing and learning. Thesis papers produced at the end of the doctoral program will also reflect the original positioning of the thesis work within a bouquet, by including a chapter analyzing the impact of the work carried out on the "Data and AI in a sustainable and responsible approach" issue.