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DELLE MARCHE

Expert-elicited Bayesian networks to enhance the interpretative capabilities of Digital Twins of bridges

Supervisor: Prof. Eng. Fabrizio Gara

Department of Civil and Building Engineering, and Architecture (DICEA)
https://www.dicea.univpm.it/

UNIVERSITÀ POLITECNICA DELLE MARCHE

Supervisor: Prof. Eng. Fabrizio Gara

Research Group Description: the Supervisor

Supervisor brief CV

Prof. Eng. Fabrizio Gara graduated with honors at the Faculty of Engineering in Ancona in 1996 and earned a Ph.D. in Structural Engineering in 2000. He became a Lecturer at the Università Politecnica delle Marche in 2002, Associate Professor in 2015, and Full Professor in 2019 at the Department of Construction, Civil Engineering, and Architecture (DICEA). He has taught various subjects, including Earthquake Engineering and Advanced Structural Systems, and currently teaches Structural Engineering and Bridge Design for the Master's Degree in Civil Engineering.

Research topics

His research focuses on steel-concrete composite bridges, soil-structure interaction for seismic design, dynamic testing of buildings and bridges, and existing bridge assessment. He has authored 59 papers in international journals and over 70 presented at international conferences (ORCID: https://orcid.org/0000-0003-1272-0673).

Research projects and supervision

He supervises the MSCA project "FLOOD-SHAB (2024–2026)" led by Dr. Karina Buka-Vaivade and conducts research funded by the Italian MIUR. Since 2019, he has been the Scientific Coordinator for UnivPM's involvement in ReLUIS projects on bridge risk, monitoring, and assessment. He was Principal Investigator of the "PROTECT" project (2020–2022) and coordinates UnivPM's contributions to two European projects: SERA 2019 ("DYMOBRIS") and ERIES 2022 ("SCOUR&SHAKE").

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Research Group Description: the Group

Structural Engineering group

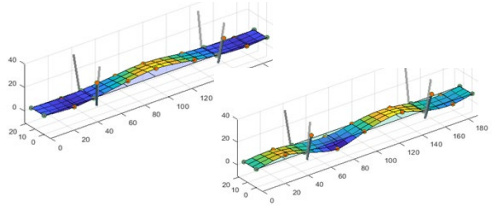
STAFF: The group is currently formed by 1 **Full Professor, 2 Associate Professors, 2 Assistant Professors 1 MSCA Research Fellow, 1 post-doc researcher, 3 PhD students and 3 master student research fellows.**

RESEARCH TOPICS

The research group specializes in bridges, with extensive experience in theoretical studies, modelling, construction, and design, particularly of steel-concrete composite ones. They are involved in inspecting, testing, and assessing existing bridges using new code procedures, including combined structural and hydraulic evaluations. The group also has significant expertise in dynamic testing and monitoring of bridges and other structures in general.
Moreover, the research group is involved in research activities relevant to the soil-structure interaction and the structural seismic protection through base isolation and dissipative devices; these topics are addressed especially in the topic of bridges.

Laboratory

On-site SHM



EQUIPMENT

The research group owns high-quality instrumentation for performing dynamic tests on structures (accelerometers, dedicated hardware and software), both on laboratory and on-site. Moreover, it has the possibility to use the Materials and Structure Testing Laboratory of the university, which is equipped with many facilities (e.g. hydraulic pump, actuators and reaction walls for static and dynamic testing, shakers). Additionally, the group has already installed many static and dynamic monitoring systems on real structures (1 bridge, 1 heritage church, 1 strategic tower building, 19 residential buildings).

UNIVERSITÀ POLITECNICA DELLE MARCHE

Supervisor: Prof. Eng. Fabrizio Gara

Department Description: DICEA

https://dicea.univpm.it/en/

The **Department of Construction, Civil Engineering and Architecture** (**DICEA**) is among the most active Italian departments of construction and civil engineering, as well as architecture, generating (*research*) and transferring (*training*) knowledge and value of the highest quality on such topics.

DICEA is arranged in 4 main sections: Architecture, Constructions, Infrastructures and Structures.

In 2017, DICEA was ranked among the best University departments of Italy (Department of Excellence) and awarded with a grant of 6,6 M€ in the period 2018-2022.
In 2022, DICEA was again ranked and then awarded with a new Department of Excellence grant (about 6,5 M€) for the period 2023-2027.

DICEA brings together a wide range of disciplines, being leading contributor to the undergraduate programmes in civil and environmental engineering, building engineering, architectural engineering. DICEA also offers postgraduate programmes in civil, environmental, building engineering and architecture.

In 2024, DICEA gathered more than 1.3 M€ of resources from international funded projects.

Coherently with the current global challenges, DICEA has individuated 4 main development axes for the next 5 years: Heritage Science; Safety of structures, infrastructures and natural systems; Digital management of constructions and built environments; Climate change, and constructions and transportation sustainability.

AT A GLANCE

2025

231 Publications

> 3.2 M€ Research income

53 Research staff

75 PhD, Post-doc, Research fellows

Teaching programs for
FIRST CYCLE DEGREE:
Building Engineering, Civil and Environmental Engineering
PROFESSIONAL DEGREE COURSE:
Technics for Territorial Design and Management
MASTER DEGREES:
Civil Engineering, Building Engineering, Environmental Engineering
SINGLE CYCLE DEGREE:
Building Engineering-Architecture

Department of Excellence (from Italian National Agency for the Evaluation of Universities and Research Institutes):
- 2018 - 2022
- 2023 - 2027

1 Digital Education Lab

Research laboratories **8**

16 Scientific Areas:
CEAR-01/A, CEAR-01/B, CEAR-03/A, CEAR-03/B, CEAR-04/A, CEAR-06/A, CEAR-07/A, CEAR-08/A, CEAR-08/B, CEAR-09/A, CEAR-10/A, CEAR-11/A, CEAR-11/B, CEAR-12/B, MATH-03/A, GIUR-04/A

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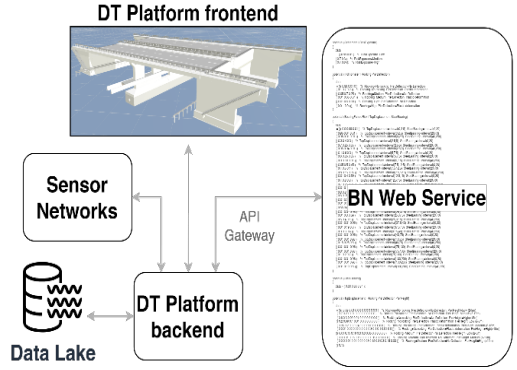
Project Idea: Expert-elicited Bayesian networks to enhance the interpretative capabilities of Digital Twins of bridges

PROJECT IDEA

Bridge management is a global concern, with many structures nearing the end of their service life and often in poor state of conservation. Managing and assessing these infrastructures is challenging due to their vast number and widespread locations, a general lack of information about existing structures, and the limitations of current inspection tools, which are often highly time-consuming. The combination of structural health monitoring (SHM) systems and artificial intelligence (AI) tools offers a promising solution for the damage patterns recognition and for predicting future scenarios, thus aiding decision-making.
This project aims to develop a tool for the probabilistic diagnosis and prediction of structural damage in bridges, utilizing Bayesian AI methods while accounting for structural, seismic, and geomorphological contexts. The approach is designed to enable the prompt detection of dangerous patterns that might otherwise go unnoticed or require lengthy expert input, thereby enhancing operational and emergency response capabilities.



PROJECT OBJECTIVES

1. To enhance the interpretative and decision-support capabilities of Digital Twins (DTs) of civil infrastructures by integrating expert-elicited Bayesian Networks (BNs) to model significant cross-domain and cross-scale relationships within complex systems.

2. To develop a methodology that contextualizes data, identifies emergent system configurations, and provides predictive insights, supporting effective decision-making and addressing limitations in current process-based and data-driven approaches.

KEYWORDS

Bridges
Expert knowledge
Bayesian networks
Assessment of existing bridges
Digital Twin
Artificial Intelligence (AI)
Statistical data processing and ML
Civil Engineering