ARCHITECTURAL HERITAGE

MUR DM 118 - Digital twinning of traditional and modern architectural heritage structures for sensing system optimization and prognosis

Funded By	MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Centro Interdipartimentale R3C Dipartimento DISEG
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Context of the research activity	Research on structural and seismic monitoring of the architectural heritage is expected to advance according to digital twin approaches, based on innovative, minimally invasive and capillary sensors, aimed at creating intelligent systems. This research programme will develop mathematical models for heritage structures using multi-physics formulations, corroborated by permanent structural health monitoring data, in addition to geometric and historical documentation. The generalization of the results will take place through AI (Machine and Transfer Learning) techniques, with the transfer of information between different monitored objects. Progetto finanziato nell'ambito del PNRR – DM 118/2023 - CUP E14D23001870006
	The growing engineering interest in the protection of cultural heritage is strongly linked to the vulnerability of the structures, mainly due to lack of engineering knowledge on: (i) the structural behavior at the time of building and its evolution; (ii) constituent materials, and (iii) the actions to be considered in the structural and seismic safety assessment stage. To address these issues, engineers exploit mechanical models that they calibrate as accurately as possible to achieve a high degree of similarity to real structural behavior. The corroboration of numerical models goes hand in hand with the so-called “path of knowledge” of a built system. It entails the achievement of adequate knowledge on several points, including history of the structure, geometry, construction details, materials, and soil-structure interaction. The models can be improved and used for several purposes, e.g. evaluate the health of the structure (diagnosis); assess the degradation safety condition (prognosis); and estimate structural and seismic upgrading measures. The most advanced step in the path of knowledge of an architectural heritage structure consists in the definition of a virtual shadow or digital twin,

Objectives	as close as possible to the system under observation, not only from a geometric and material point of view, but above all from a mechanical point of view. The model corroboration process not only allows the consistency of the different experimental information to be checked, reducing the uncertainties of virtualization, but above all creates a predictive tool for preservation, especially in cases where the principle of minimum intervention applies. One of the main problems of the digital twinning is the conceptualization of virtual models that are able to reproduce quite accurately the behavior of the physical object (be it a mechanical or physical behavior) with a minimum computational effort. To reach this milestone, a deep research for theories and models that explore behaviors that go beyond the classical continuum theory, e.g., Finite Element (FE) method, is needed for cultural heritage structures, contemplating synergistic approaches to modeling, for example by resorting to multi-theories (e.g., Discrete Element (DE) method interconnected to FE method) or directly by resorting to experimental data that partially or wholly replace parts of the digital twin, e.g., grey-box approaches. The automation of the interconnection of data, the balance between key aspects to include and computational efficiency, theories and modeling approaches is still an open issue in digital twinning, thus, this research programme intends to stimulate a multi-disciplinary debate about harmonizing heterogeneous information, making use of the skills and tools made available by the R3C interdepartmental centre. Finally, one of the crucial problems that this research will address is the need to extend the experimental data from the few architectural assets on which permanent (static and/or seismic) monitoring systems are installed to larger classes of structures. The research will therefore address the problem of the combined use of model-driven and data-driven approaches (e.g. Machine Learning and Transfer Learning), also through data from monitoring systems currently analyzed by the Earthquake Engineering & Dynamics laboratory of the Turin Polytechnic (e.g. domes of the Sanctuary of Vicoforte and of Santa Caterina church in Casale Monferrato).

Skills and competencies for the development of the activity	Ideal candidates should have a background compatible with the proposed research and the topics listed, but above all they should show an open mind and a strong motivation to address multidisciplinary issues. A propensity for theoretical and experimental research is expected, demonstrable for example with involvement in advanced research topics in their thesis work. Knowledge and interests in the field of earthquake engineering, architectural heritage, modeling, structural health monitoring, structural identification, machine learning, sensors are appreciated, together with some basic research experiences related to the selected Ph.D. topic. Both the curriculum examination and the interview are aimed at evaluating the potential of candidates to develop innovative research activity that leads to exceptional scientific results.