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ENABLING SUPERVISED LEARNING IN STRUCTURAL HEALTH MONITORING BY SIMULATING DAMAGED RESPONSES THROUGH PHYSICS BASED MODELS

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The health of civil structures cannot be addressed by means of in situ inspections alone, as they provide information related to the inspection time interval only. As structural safety must be continuously monitored, mature sensor technology and algorithms capable to dig into large datasets have to be exploited for automated and online structural performance assessments.
The pattern recognition paradigm has been adopted in case of continuous data inflow, to detect the onset and propagation of a structural damage [1]. It typically consists of four stages: operational evaluation, data acquisition, feature selection, and statistical modelling for feature discrimination. The latter stage allows establishing a mapping between so-called damage sensitive features of the data and the underlying damage state. Physics-based models of this mapping can be hardly defined for real-life structural systems; in such cases, Machine Learning (ML) techniques can be adopted to automatically learn the said case-dependent, damage sensitive features and effectively exploit them in a statistical framework. The main limitation of this pattern recognition paradigm is the unavailability of data related to all the possible damage conditions, forcing to adopt an unsupervised learning context for ML training. This context enables robust anomaly detection, but it handles damage localisation and quantification with difficulty.
The use of physics-based models copes with this drawback, by simulating the structural response, in terms of e.g. measurable dynamic response to the external actions, in the presence of a damage. This allows for enlarging training datasets with labelled data, and, finally, to train ML algorithms, such as the employed fully convolutional networks [2], that require the adoption of a supervised learning paradigm. Reduced Order Modelling techniques are exploited to speed-up the construction of the training dataset [3]. When new measurements become available online, the trained ML algorithm allows selecting the most probable damage state linked to them, reducing modelling uncertainties.
The potentiality of the adoption a supervised learning framework in structural health monitoring is here assessed through some numerical examples mimicking real-life cases, for which training datasets are built by gathering pseudo-experimental structural responses, provided as displacement and/or acceleration recordings and generated via Finite Element models.

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