Dealing with uncertainties in structural damage localization by reduced order modeling and deep learning-based classifiers

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Trying to localize structural damages, starting from online acquired data, is a complex task hampered by several sources of uncertainties. Indeed, the response of a structure is not affected just by the onset and propagation of damage, but also depends on loading and environmental conditions. To distinguish between the different sources of variability of a system, a statistics-based classifier is employed [1]. Its design is based on a deep learning architecture, featuring a three-layers fully convolutional network for sake of pattern recognition in the data [2]. The convolutional layers map the input data into linearly separable classes, each one featuring a possible damage state. The classification is done by associating a confidence level to each class. To train the classifier, a synthetic dataset is numerically generated in an offline phase by using a numerical model (playing the role of digital twin) of the structure. The more representative the training dataset of the damage and working conditions undergone by the structure, the better the prediction capability of the classifier on online acquired data. For this reason, it is extremely important to define the most plausible scenarios that might be experienced by the structure, and to include them in the training dataset in a statistically representative way. A certain number of parameters, controlling the working conditions and the material properties in different subregions of the structure, are introduced with associated effective statistical distributions to attain this goal. Due to the adopted stochastic framework, the construction of the training dataset may require a great number of model evaluations, typically unaffordable from a computational point of view. Instead of relying on "expensive" full order models (e.g. based on the finite element method), a reduced order modelling approach is adopted to reduce the cost of each model evaluation, allow the creation of larger statistically-representative dataset and, at a later stage, ensure the effectiveness of the whole procedure [3]. Parametric model order reduction techniques are adopted to handle the dependency of the system on working and damage conditions, and, whenever this dependency implies the re-assembling of the full order model numerical operators, extremely expensive from a computational point of view, hyper-reduction is exploited [4].

References

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