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DEEP LEARNING FOR LOCAL DAMAGE IDENTIFICATION IN LARGE SPACE STRUCTURES VIA SENSOR-MEASURED TIME RESPONSES

Abstract

Due to the stringent requirements imposed by state-of-the-art technologies, most of modern spacecrafts are now equipped with very large substructures such as antennas, deployable booms and solar arrays. However, while the size of these elements increases, their mass is limited by the rocket maximum take-off weight and, therefore, they result to be lightweight and very flexible. A natural concern derived from this trend is that these structures are now more susceptible to possible structural damages during launch phase or operational life (impacts, transient thermal states and fatigue). In fact, for the increasing importance of the issue, damage detection in aero-space structures has been studied extensively in the last decades, employing both data and model-driven solutions. Since the degradation of some structural elements would naturally result in a modification of the system dynamical behaviour, damage detection processes are usually performed by comparing the dynamical responses or the structural model matrices (i.e. stiffness, mass and damping) of the undamaged model with those of the damaged structure. However, for large structures the presence of local damage does not generally induce substantial change in the global dynamic which makes the local failures difficult to detect. A methodology for structural damage detection based on data-driven Deep Neural Network (DNN) techniques is hereby proposed for the study of a large in-orbit flexible system. DNNs are widely used in a plethora of supervised learning problems, with applications in various contexts, given their great generalization capability. The architecture evaluated in this work is composed by stacking Long Short-Term Memory blocks (the state-of-the-art DNN for time series processing), combining them with non-linear activations layer and fully-connected blocks. The resulting deep model is put in use to detect the structural damages, formulating the problem as a sequence-to-label classification one. In order to generate data for training and testing the machine learning model, different damage scenarios are generated via Finite Element (FE) commercial code and, based on the extracted modal parameters, the fully coupled 3D equations for the flexible spacecraft are integrated to test typical profiles of attitude manoeuvres. The DNN model is trained using the sensor-measured time series responses, where each of the former has been associated with the label of the corresponding damage scenario. Finally, the effectiveness of the proposed DNN model will be verified numerically simulating typical mission scenarios and insights of its performance in presence of modelling uncertainties and noisy measurements will be given.