Unsupervised Deep Learning Approach To Damage Detection And Localization Using Lamb Waves

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Condition-based maintenance policies have gained importance during the past years as strategies to increase structural safety levels. This approach leverages on the potentialities of structural health monitoring methods to drive maintenance actions when damage affecting structures is identified. To this purpose, sensors need to be permanently installed on the structure to monitor signals carrying damage-related information. This approach has been proved to be particularly efficient for thin-walled structures, where diagnostic capabilities of Lamb waves are usually exploited to characterize possible damage. Lamb waves are typically processed either through tomographic algorithms to generate damage probability maps, usually using the reconstruction algorithm for the probabilistic inspection of damage (RAPID), or by employing machine learning methods to directly detect, localize and/or quantify anomalies. Within the latter class of methods, supervised deep neural networks have been proposed in the literature that outperform classic tomographic algorithm-based approaches, even though big data is required to train the networks and satisfactorily diagnose damage. Such a limitation is typically overcome in the field of machine learning by employing more complex models, such as unsupervised machine learning algorithms, which have not been properly considered in structural health monitoring applications yet. In this work, unsupervised deep neural networks, specifically convolutional autoencoders, are employed to process Lamb waves acquired through a network of piezoelectric sensors installed on the structure. The information provided by the networks is processed through a dedicated localization algorithm and properly aggregated to perform damage detection and localization. The capabilities of the proposed framework are demonstrated through a case study involving a plate-like structure and its diagnostic performance is compared to that provided by the RAPID algorithm.