Modal filter synthesis with use of artificial neural networks

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A modal filter is a tool developed in the early 1980s to improve the performance of modal control [1]. In subsequent years, modal filtering has found other applications, such as input identification, modal model comparison, and damage detection and localisation. This last application is particularly interesting, as it effectively identifies damage, lends itself well to automation, and demonstrates low sensitivity to ambient conditions [2]. A significant difficulty in using modal filtering for damage detection is the filter synthesis itself. It requires an identified modal model, and therefore experimental modal analysis. In summary, a modal filter enables the selective extraction of individual vibration modes from the system's dynamic response, whereas its classical synthesis requires knowledge of modal parameters determined by modal analysis methods. Due to the growing demand for automated diagnostic processes, the use of artificial intelligence methods has been proposed as an alternative to classical computational procedures. Convolutional artificial neural networks (CNN) [3] were chosen as a tool for determining modal filter coefficients directly from measurement characteristics.

As part of the research, software was developed to generate training data for variant numerical models of linear mechanical systems with two and four degrees of freedom. Random variation of mass, stiffness, and damping parameters, along with various connection topologies, was considered. Based on this, a dataset was generated comprising spectral transfer functions and corresponding modal filter coefficients determined using classical modal filtering, with a maximum of 10,000 sets. Training data was then prepared, and the architecture of a convolutional neural network (CNN) implementing the regression task was designed. Various network architectures and network parameter settings, along with different training data sizes, were tested. The obtained results did not fully confirm the feasibility of using CNNs for modal filter synthesis.

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