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Automated Modal-Based FE Model Updating of a Medieval Masonry Tower Using Genetic Algorithm and Particle Swarm Optimization

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Extended Abstract

Masonry bell towers are a significant part of the historical assets of Italy, whose preservation against human-induced or natural risks is essential for decision-makers. These slender masonry structures are highly prone to vibrations from human activities, such as motor-vehicle traffic and construction operations, as well as from bell ringing and seismic excitations. Finite element models (FEM) are widely recognized as essential numerical tools for active structural health monitoring, enabling the analysis and simulation of complex structural behavior. The rapid development of new and continuous improvement of existing numerical modeling methods has increased the need for improved reliability and precision of models to predict structural responses and detect damage realistically. This study focuses on improving the accuracy of finite element models (FEM) for these vulnerable masonry structures using advanced updating techniques. Finite element model updating (FEMU), framed as a minimization problem, is the process of calibrating model parameters based on the actual dynamic properties of a structure obtained from operational modal analysis (OMA), such as natural frequencies, mode shapes, and damping ratios. The purpose is to determine the optimal unknown parameters of the model, such as elastic moduli, mass densities, constraints, and boundary conditions, to minimize the objective function that quantifies the discrepancy between experimental and numerical modal properties. This research advances previous work on the medieval bell tower of San Giuseppe in Aci Castello, which relied on manual model updating through trial and error using experimental data. Here, manual FEM updating is replaced by nature-inspired optimization techniques to reinforce the accuracy and efficiency. The FEM of the bell tower, developed in OpenSeesPy, is calibrated employing Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) to match natural frequencies and mode shapes obtained through OMA. The results demonstrate the effectiveness and efficiency of both algorithms in automating the updating process and improving the model accuracy. This study not only increases FEM reliability but also provides insights for further methodological improvements in structural health monitoring.

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