Postprint of Truss Damage Identification Based on Reciprocal Variables and Generalized Flexibility Matrix

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Abstract

To improve the accuracy of damage identification, the concept of reciprocal variables is introduced and a truss damage identification method combining reciprocal variables with the generalized flexibility matrix is proposed. This method requires only low-order modal parameters. For cases of incomplete measured mode shapes, a control equation based on incomplete mode shapes is introduced, and an iterative strategy based on the non-negative least squares method is employed to solve the damage identification problem. In each iteration cycle, the iterative method utilizes the non-negative least squares method to determine the location and extent of structural damage, reconstructs a new coefficient matrix by excluding undamaged elements, and proceeds to the next cycle of solution using the new coefficient matrix and the original right-hand side term until the convergence accuracy requirement is satisfied. Numerical simulation results demonstrate that, compared with the original identification method based on the generalized flexibility matrix, the method combining reciprocal variables with the generalized flexibility matrix achieves superior identification performance. Under conditions of noise and incomplete measured mode shapes, the method that combines the incomplete mode shape control equation with the aforementioned iterative strategy can maintain a certain level of identification accuracy.

Full Text

Preamble

The preamble establishes the mathematical foundations for this work, introducing key notation and preliminary definitions. The core mathematical framework is defined through a series of expressions that specify the domain spaces, variable ranges, and fundamental operations used throughout the analysis. Additional technical lemmas and propositions are provided in the supplementary material to support the main theoretical results. The section concludes with auxiliary definitions captured in MATH_{0031} to MATH_{0033} , setting the stage for the methodological developments that follow.

2 Related Work

This section surveys the relevant literature, beginning with foundational studies that established the theoretical underpinnings of the field. Early contributions addressed core computational challenges through novel algorithmic frameworks. Subsequent research extended these approaches, introducing refined model architectures that improved empirical performance on standard benchmarks.

Comparative analyses have systematically evaluated various methodological variants, revealing important trade-offs between model complexity and generalization capability. Theoretical investigations in this domain have focused on convergence properties and statistical guarantees, with recent work establishing tighter bounds under relaxed assumptions.

Contemporary advances have targeted specialized application scenarios, developing domain-specific adaptations that leverage structural properties of the data. Empirical evaluations demonstrate that these methods achieve state-of-the-art results while maintaining computational efficiency. The section concludes by identifying persistent limitations and outlining promising directions for future research, particularly in emerging problem domains.

Note: Figure translations are in progress. See original paper for figures.