Automated Multi–Level Substructuring for Nonlinear Eigenvalue Problems

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Over the last few years, a new method for performing frequency response and eigenvalue analysis of complex finite element (FE) structures known as Automated Multi-Level Substructuring (AMLS for short) has been developed [1, 2].

In AMLS the large finite element model is recursively divided into many substructures on several levels based on the sparsity structure of the system matrices. Assuming that the interior degrees of freedom of substructures depend quasistatically on the interface degrees of freedom, and modeling the deviation from quasistatic dependence in terms of a small number of selected substructure eigenmodes, the size of the finite element model is reduced substantially yet yielding satisfactory accuracy over a wide frequency range of interest. Recent studies ([4], e.g.) in vibro-acoustic analysis of passenger car bodies where very large FE models with more than one million degrees of freedom appear and several hundreds of eigenfrequencies and eigenmodes are needed have shown that AMLS is considerably faster than Lanczos type approaches.

To generalize the AMLS method to nonlinear eigenproblems

$$T(\lambda)x = 0 \tag{1}$$

we identify an essential linear part of $T(\cdot)$, i.e. we rewrite problem (1) as

$$Kx - \lambda Mx - R(\lambda)x = 0, \tag{2}$$

where $K \in \mathbb{C}^{n\times n}$ and $M \in \mathbb{C}^{n\times n}$ are Hermitian and positive definite matrices, and

$$R(\lambda) = K - \lambda M - T(\lambda) \tag{3}$$

is a perturbation of the linear eigenproblem $Kx = \lambda Mx$, which is not necessarily small but has a small influence on the eigenparameters and eigenvectors of interest. The efficiency of AMLS is demonstrated by a gyroscopic eigenproblem [3] modeling a rotating tire, and rational eigenproblems modeling vibrations of a fluid–solid structure and damped vibrations of a structure. This is joint work with Kolja Elssel.

References

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