A Krylov-based trust region scheme for model updating

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We consider the problem of optimizing finite element models arising from structural analysis of buildings using some free parameters describing the mechanical characteristics of the underlying materials. This problem — usually known in engineering as *model updating* — arises when trying to match the theoretical characteristic frequencies predicted by the finite element model with the ones recovered using accelerometers combined with a system identification approach. In particular, one desires to optimize the eigenvalues at the lowest end of the spectrum of a symmetric definite pencil $K(\mathbf{x}) - \lambda M(\mathbf{x})$, depending on a vector of ℓ parameters $\mathbf{x}$. A relevant application is understanding the characteristic of unknown materials, whose properties cannot be analyzed directly because of lack of samples [3].

We describe the numerical challenges in tackling large scale problems (with typically more than 10^5 degrees of freedom for 3D models) — where repeated computation of the eigenvalues for many values of $\mathbf{x}$ is often too expensive. For this reason, we rely on a trust region optimizer to efficiently perform the optimization task. To this end, we need a local model of the objective function that approximates it cheaply. The model can be obtained by a slightly modified inverse Lanczos projection, based on the one used to approximate the smallest eigenvalues. The idea is to re-use the projection space at one point also in a small neighborhood (similarly to Krylov recycling methods [2]), and update the projection computing a first order local approximation of $K(\mathbf{x})^{-1}$, and of the inner product induced by $M(\mathbf{x})$. This approximation can be interpreted as an instance of parametric model order reduction [1].

We show that this choice provides a first-order accurate local model, and that this can be used to prove the convergence of the scheme. In particular, the obtained method allows to optimize the frequency response of the buildings to match the one experimentally recovered at the cost of very few evaluations of the objective function. Several practical examples are shown, that further confirm the applicability and efficiency of the method.

References

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