Using Model Order Reduction for Quasi-Newton Optimization of Structures and Vibrations

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Abstract

In many engineering problems, the behavior of dynamical systems depends on physical parameters. In design optimization, these parameters are determined so that an objective function is minimized. For applications in vibrations and structures, the changes in parameters will affect the Frequency Response Function (FRF), and our objective is often to minimize the 2-norm or the ∞-norm of the an FRF over a given frequency range by optimizing it in the parameter space. For many of these applications, the orders of the systems are large and numerical optimization is expensive.

In this paper, we propose the combination of Quasi-Newton type line search optimization methods and Krylov-Padé type algebraic Model Order Reduction (MOR) techniques to speed up numerical optimization of dynamical systems. Conventional MOR methods reduce only on the frequency ω and Parametric MOR (PMOR) methods reduce on design parameters as well as ω. But when we have many parameters, it is impractical to use PMOR to reduce on all these parameters. Therefore, we have two types of parameters in the reduced model: 1.) a *free parameter* is allowed to change in the reduced model; 2.) a *fixed parameter* can only take a specific value in the reduced model. We prove that Krylov-Padé type MOR allows for fast evaluation of the objective function and its gradient, thanks to the moment matching properties for the objective function, its derivatives towards the free parameters and its first order derivatives towards the fixed parameters.

Based on these results, we propose two frameworks to integrate (P)MOR into Quasi-Newton type optimization methods: 1.) *MOR Framework* uses one reduced model on ω to reduce the computational cost of each FRF; 2.) *PMOR Framework* uses one reduced model on both ω and the line search direction to reduce the computational cost of all FRFs on the searched direction. We show that both of these two frameworks lead to significant speed-ups. In addition, for ∞-norm optimization, PMOR framework is more efficient.

Keywords: (Parametric) Model Order Reduction, Krylov Methods, Quasi-Newton Optimization, Design Optimization, Structures and Vibrations.