Model order reduction of parametrized structural dynamics equations

José V. Aguado*, Santiago Montagud*, Francisco Chinesta*, Elías Cueto†, Antonio Huerta††

* GeM Institute (UMR 6183 CNRS) at Ecole Centrale de Nantes
1 rue de la Noë, 44321 Nantes cedex 3, France
{jose.aguado-lopez;santiago.montagud;francisco.chinesta}@ec-nantes.fr
https://rom.ec-nantes.fr/

† Aragon Institute of Engineering Research (I3A), Universidad de Zaragoza
María de Luna 3, 50018 Zaragoza, Spain
ecueto@unizar.es

†† Laboratori de Càlcul Numèric (LaCaN), Universitat Politècnica de Catalunya
BarcelonaTech, 08034 Barcelona, Spain
antonio.huerta@upc.es

ABSTRACT

This paper is concerned with the solution of parametrized structural dynamics models applying model order reduction techniques. Structural dynamics is a pioneering field in which model order reduction techniques were early applied. Semi-discretization of the equations of motion leads to a system of Ordinary Differential Equations (ODE) that can be solved using a time-integration scheme. This procedure, although conceptually simple, is computationally expensive for systems involving a large number of degrees of freedom. Modal analysis was introduced aiming at reducing the complexity of such system of ODEs. The following steps apply: i) compute the leading eigenvectors from the unforced problem; ii) project the forced problem onto the subspace generated by those eigenvectors; iii) integrate the system of ODEs expressed in terms of the modal coordinates. Notice that the displacement field is expressed as a sum of space-time separated functions. This can clearly be seen as a special case of model order reduction in which the reduced basis is formed from the eigenvectors. But this is not the only possible choice. Indeed, it may not be the most suitable choice when parametrized models are of interest, as they lead to a parameter dependent eigenvalue problem. In particular, if damping is considered, a parameter dependent quadratic eigenvalue problem must be solved to compute properly the eigenvectors. To avoid solving this eigenvalue problem, in this paper we propose an alternative approach based on the Proper Generalized Decomposition method. The technique here presented is closely related to harmonic analysis, and therefore it is only concerned with the long-term forced response. Besides the parametric dependence already considered, harmonic analysis introduces a *intrinsic* parametric dependence on the frequency. However, with the PGD it is possible to obtain very efficiently the displacement field (in the frequency space) for any forcing frequency and any parameter value inside predefined ranges. This is achieved by computing a space-frequency-parameter separated representation. This approach offers several advantages: i) there is no need to solve the unforced (eigenvalue) parametrized problem; ii) the space-time solution can be recovered with a simple Fourier inverse transform (there is no need of performing a time integration); iii) the PGD solution is valid not only for one particular forcing term but for any forcing term that can be written as a combination of the considered frequencies (linearity); and iv) the solution is available for any value of the parameter.

REFERENCES

[1] F. Chinesta, P. Ladeveze and E. Cueto, “A short review on model order reduction based on Proper Generalized Decomposition”, Arch Comput Methods Eng, 18(4), 395-404 (2011).