Non-intrusive adaptive surrogate modeling of parametric frequency-response problems

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Numerical methods for time-harmonic wave propagation phenomena are often computationally intensive, especially in mid- and high-frequency regimes, making a direct frequency response analysis prohibitively expensive. In this framework, starting from few expensive solves of the problem, model order reduction (MOR) methods can provide a reliable and cheap-to-evaluate approximation of the frequency response of the system. In this talk, we describe an MOR approach for parametric frequency-response problems, where the high-fidelity problem

\[
\begin{align*}
& zE(p)x(z,p) = A(p)x(z,p) + b(z,p) \\
& y(z,p) = C(p)x(z,p) + d(z,p)
\end{align*}
\]

models not only the impact of the frequency $z$ on the system response, but also that of additional design and/or uncertain parameters $p$. Our approach is non-intrusive, i.e., we do not require access to the matrices/operators defining the underlying high-fidelity problem.

Our proposed method relies on \textit{minimal rational interpolation} \cite{2} for the surrogate modeling of the frequency dependence, for few fixed values of the parameters $p \in \{p_j\}_{j=1}^T$. In this step, only the dependence on $z$ is taken into account, and the $T$ resulting surrogates $\{\tilde{y}_j\}_{j=1}^T$ (with $\tilde{y}_j(z) \approx y(z,p_j)$ for all $j$) are rational functions of $z$. We describe how an adaptive selection of the frequency sample points can be carried out even in a non-intrusive framework.

Then, the $T$ different $z$-surrogates, properly converted to a modal form

\[
\left\{\tilde{y}_j : z \mapsto \sum_i \frac{r^j_i}{z - \lambda^j_i}\right\}_{j=1}^T,
\]

are combined to obtain a global approximation with respect to both frequency and parameters \cite{1}. We also describe how locally adaptive sparse grids can be applied over $p$-space to (i) weaken the curse of dimension and (ii) perform non-intrusively an adaptive sampling of the parameters.

Numerical examples in modeling of electrical circuits and elasto-dynamic systems will also be presented, providing evidence of the approximation quality and computational efficiency of the surrogate models obtained with the proposed technique.

\textbf{References}
