POLITECNICO DI TORINO
Repository ISTITUZIONALE

High-dimensional data driven parameterized macromodeling

Original
High-dimensional data driven parameterized macromodeling / Zanco, Alessandro. - (2022 Sep 27), pp. 1-216.

Availability:
This version is available at: 11583/2971991 since: 2022-10-03T11:35:46Z

Publisher:
Politecnico di Torino

Published
DOI:

Terms of use:
Altro tipo di accesso

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)

08 February 2023

Politecnico di Torino, Doctoral Program in Electrical, Electronics and Telecommunications
Engineering (XXXIV cycle).
Doctoral dissertation.

High-dimensional data-driven parameterized macromodeling

Ph.D. Candidate: Alessandro Zanco

Supervisor: Prof. Stefano Grivet Talocia

Dissertation Summary

Mathematical modeling has become essential for the electronic industry. Today's market necessities demand to match the conflicting requirements of increasingly faster workflows, together with reliable and accurate designs. Assessing the robustness of designs may be extremely challenging, due to the presence of increasingly miniaturized devices, in conjunction with high-frequency signals and other interfering components placed in close proximity to each other. In this context, modeling the impact of distributed effects on the reliability of complex designs demands for sophisticated simulation software that, solving first-principle equations (e.g., Maxwell's equations), are capable of accurately predicting their electrical and electromagnetic behaviors.

However, the impressive accuracy levels achieved by first-principle solvers come at the cost of prohibitively long runtimes, that badly fit the above-mentioned design requirements. In this scope, the use of simplified reduced-order behavioral models (or, macromodels) is extremely helpful. Retaining only a reduced set of auxiliary variables necessary to accurately reproduce the input/output behavior or interest, macromodels can replace the original fully detailed description, enabling for exceptionally fast simulations with a minimal and controlled error.

The possibility of embedding in the macromodel the variability upon some parameters, would additionally enable cheap repeated simulations under different configurations of the structure of interest and different environmental conditions, allowing for variability, optimization and design centering analyses that would be impractical with first-principle solvers. This manuscript fits in this last parameterized framework where, although well-consolidated parameterized macromodeling strategies are already available, major open problems are still to be addressed. Throughout this work we will consider data-driven approaches, so that parameterized models are constructed from a reduced set of frequency-domain data, available from simulation.

First, we address the problem of certifying the model stability and passivity, which are fundamental properties that the model must have to be of practical use in design flows. A first set of approaches propose to build parameterized models that are stable and passive by construction, at the cost of a reduced portability and lack of compactness. Others, instead, enforce these properties employing a post-processing perturbation strategy, guaranteeing the model compactness. In this second framework, prior to this work only partial solutions were available,

that were limited to one parameter only. The first technical contribution of this work is an extension of the latter approach to higher-dimensional parameter spaces. Formulating a parameter-dependent Hamiltonian matrix, we set up a scalable algorithm for the identification of stability and passivity violations, to be removed in a subsequent post-processing phase.

Then, we address the problem of *high-dimensional* macromodeling, i.e., the inclusion of a much larger number of parameters in the model, that would be much more flexible since representative of a wider set of design and working conditions. Standard parameterized macromodeling strategies are not suited for high-dimensional tasks, since their identification procedures become exponentially more complex as the number of parameters increases. The second technical contribution of this work is the formulation of a high-dimensional model form based on *Radial Basis Functions*, that is specifically suited to handle many more parameters without incurring in computational issues. In addition, we also introduce an innovative set of uniform stability constraints, whose formulation does not depend on the number of parameters and, thus, perfectly fits the considered high-dimensional setting.

The last contribution of this thesis is the formulation of a comprehensive set of strategies, specifically aimed at optimizing, based on the dataset at hand, the dimension of the approximation spaces and the hyper-parameters of the radial basis functions, basically without any user interaction. This enables the development of a high-dimensional fully automated macromodeling flow that autonomously optimizes the model structure and generates accurate high-dimensional and guaranteed stable models.

In summary, this dissertation provides advancements under both a theoretical and a practical viewpoint. The improvements with respect to prior research works are documented with relevant numerical examples, demonstrating that the results of this work are ready for exploitation.