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Model Reduction for Efficient Simulation of MEMS

Introduction

I have joined Prof Korvink in 2001 when I came to work on an EU project to build a mathematical model and make simulation for a microthruster. Prof Korvink holds a chair in simulation at IMTEK. Good introduction to Prof Korvink's chair is the review [1]. The goal of his chair is to bridge the gap between engineering requirements during design and system-level simulation and existing commercial software.

One of the project goals was to develop so called a compact model that can be used during system level simulation when finite element models are prohibitive even for modern computers. Compact modeling is very popular among electrical engineers (see [2] for more detail) but it heavily relies on intuition. Fortunately quite soon, we have found papers on formal model reduction and understood that it can be used to generate compact models directly from finite element models almost automatically. I became a group leader on model reduction at Prof Korvink's chair. Below I describe the research strategy and results obtained for the last five years.

Research Strategy and Results

I am a chemist by background. In chemistry, any new research must start with a thorough literature analysis (with a surprise I have found that in engineering this is not always the case). The result of my literature work is the review [3]. In parallel, we have applied implicit moment matching via the Arnoldi process to simple engineering applications [4] and seen that this is exactly what we needed. As a result, we have identified our niche among groups working on model reduction at that time as follows:

- Follow work of mathematicians in this area;
- Develop software to perform model reduction directly to finite element models made in commercial software;
- Identify MEMS applications suitable for model reduction and collaborate with engineers to apply model reduction for their problems;
- Develop methodology to use model reduction in design flow and system-level simulation.

Below I will briefly describe the results achieved for the four years of work.

We became a part of a mathematical community working on model reduction (for example, see Ref [2]). We developed for mathematicians Oberwolfach model reduction benchmark collection [5] (http://www.imtek.uni-freiburg.de/simulation/benchmark/) and, on the other side, were all the time informed about the latest development in this area.

I have written MOR for ANSYS (former mor4ansys) [6] (http://www.imtek.uni-freiburg.de/simulation/mor4ansys/) that reads system matrices directly from binary ANSYS files and runs model reduction. It is written in C++ and at present can work for finite element models up to 1 000 000 degrees of freedom on a computer with 4 Gb of RAM.

Because of MOR for ANSYS, the collaboration with engineering groups happens to be relatively easy. Below is a list of our collaborators with whom we have joint papers:
Solution of an engineering problem brings forward many things that must be solved even though a relevant mathematical theory is missing. In this case, an engineering practice to proceed is to rely on heuristic approaches based on observations and experience. Ref [7] is a good example in this respect on how we tried to solve the problem to choose the dimension of a reduced model for the Arnoldi process when the error estimate is missing.

In Ref [8], we have used model reduction within an optimization process and in Ref [9] we have researched another important topic: how to connect reduced model between each other. Refs [10] present methodology to apply model reduction during electro-thermal simulation.

Since the beginning, we have seen that conventional model reduction lacks an important feature required by many engineering applications. If one changes something in the system matrices then model reduction must be repeated again. We have started research on how to overcome this limit and our first results are presented in Refs [11][12]. In my view, this opens a new way to solve an optimization problem.

**Journal Papers adn Book Chapters**


Conference papers

Papers are available at http://www.imtek.uni-freiburg.de/simulation/mor4ansys/publicationsByYears.html

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