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Oberwolfach Benchmark Collection

Jan G. Korvink and Evgenii B. Rudnyi

Institute for Microsystem Technology, Albert Ludwig University
Georges Köhler Allee 103, 79110 Freiburg, Germany
{korvink,rudnyi}@imtek.uni-freiburg.de

Summary. A Web-site to store benchmarks for model reduction is described. The site structure, submission rules and the file format are presented.

11.1 Introduction

Model order reduction is a multi-disciplinary area of research. The driving force from industry are engineering design requirements. The development of theory to solve these problems remains clearly in the hands of mathematicians. Numerical analysts and programmers are solving issues of an efficient, reliable and scalable implementation.

A benchmark is a natural way to allow different groups to communicate results with each other. Engineers convert a physical problem into a system of ordinary differential equations (ODEs) and specify requirements. Provided the system is written in a computer-readable format, this supplies an easy-to-use problem in order to try different algorithms for model reduction and compare different software packages.

During the Oberwolfach mini-Workshop on Dimensional Reduction of Large-Scale Systems, IMTEK agreed to host as well as develop rules for a related benchmark Web site. The site is running since spring of 2004 at `http://www.imtek.uni-freiburg.de/simulation/benchmark/` and the rules are described below.

The file format to represent a nonlinear system of ODEs has been developed during the joint DFG project between IMTEK, Freiburg University and Institute of Automation, University of Bremen: The Dynamic System Interchange Format (DSIF, `http://www.imtek.uni-freiburg.de/simulation/mstkmpkt/`). It is presented in Chapter 12 where also the background for model reduction benchmarks is described in more detail.

Unfortunately, there are two problems with the DSIF format. First, it does not scale well to high-dimensional systems. For example, when a benchmark for a system of linear ODEs of dimension of about 70 000 with sparse system

matrices containing about 4 000 000 nonzeros has been written in the DSIF format, Matlab 6 crashed while reading the file. Second, it is not easy to parse it outside of Matlab. As result, we present an alternative format to store linear ODEs based on the Matrix Market format [BPR96]. For nonlinear ODE systems, the DSIF format seems to be the only alternative and we highly recommend its use in this case.

11.2 Documents

The collection consists of documents, benchmarks and reports. A benchmark and a related report may be written by different authors.

Each document is written according to conventional scientific practice, that is, it describes matters in such a way that, at least in principle, anyone could reproduce the results presented. The authors should understand that the document may be read by people from quite different disciplines. Hence, abbreviations should be avoided or at least explained and references to the background ideas should be made.

11.2.1 Benchmark

The goal of a benchmark document is to describe the origin of the dynamic system and its relevance to the application area. It is important to present the mathematical model, the meaning of the inputs and outputs and the desired behavior from the application viewpoint.

A few points to be addressed:

- The purpose of the model should be explained clearly. (For instance, simulation, iterative system design, feedback control design, ...)
- Why should the model be reduced at all? (For instance, reducing simulation time, reducing implementation effort in observers, controllers...)
- What are the QUALITATIVE requirements of the reduced model? What variables are to be approximated well? Is the step response to be approximated or is it the Bode plot? What are typical input signals? (Some systems are driven by a step function and nothing else, others are driven by a wide variety of input signals, others are used in closed loop and can cause instability, although being stable themselves).
- What are the QUANTITATIVE requirements of the reduced model? Best would be if the authors of any individual model can suggest some cost functions (performance indices) to be used for comparison. These can be in the time domain, or in the frequency domain (including special frequency band), or both.
- Are there limits of input and state variables known? (Application related or generally)? What are the physical limits where the model becomes useless/false? If known a-priori: Out of the technically typical input signals, which one will cause "the most nonlinear" behavior?

If the dynamic system is obtained from partial differential equations, then the information about material properties, geometrical data, initial and boundary conditions should be given. The exception to this rule is the case when the original model came from industry. In this case, if trade secrets are tied with the information mentioned, it may be kept hidden.

The authors are encouraged to produce several dynamic models of different dimensions in order to provide an opportunity to apply different software and to research scalability issues. If an author has an interactive page on his/her server to generate benchmarks, a link to this page is welcomed.

The dynamic system may be obtained by means of compound matrices, for example, when the second-order system is converted to first-order. In this case, the document should describe such a transformation but in the datafile the original and not the compound matrices should be given. In this way, this will allow users to research other ways of model reduction of the original system.

11.2.2 Report

A report document may contain:

a) The solution of the original benchmark that contains sample outputs for the usual input signals. Plots and numerical values of time and frequency response. Eigenvalues and eigenvectors, singular values, poles, zeros, etc.

b) Model reduction and its results as compared to the original system.

c) Description of any other related results.

We stress the importance to describe the software employed as well as its related options.

11.2.3 Document Format

Any document is considered as a Web-page. As such it should have a main page in the HTML format and all other objects linked to the main page such as pictures and plots (GIF, JPEG), additional documents (PDF, HTML). In particular, a document can have just a small introductory part written in HTML and the main part as a linked PDF document.

The authors are advised to keep the layout simple.

Scripts included in the Web-page should be avoided, or at least they should not be obligatory to view the page.

Numerical data including the original dynamic system and the simulation results should be given in a special format described below.

11.3 Publishing Method

A document is submitted to IMTEK in the electronic form as an archive of all the appropriate files (tar.gz or zip) at `http://www.imtek.uni-freiburg.de/`

`simulation/benchmark/`. Then it is placed in a special area and enters a reviewing stage. Information about the new document is posted to a benchmark mailing list `benchmark@elmo.imtek.uni-freiburg.de` and send to reviewers chosen by a chief editor. Depending on the comments, the document is published, rejected or sent to authors to make corrections. The decision is taken by an editorial board.

11.3.1 Rules for Online Submission

- Only ZIP or TAR.GZ archives are accepted for the submission.
- The archive should contain at least one HTML file, named `index.html`. This file represents the main document file.
- The archive must only contain files of the following types: *.html, *.htm, *.pdf, *.gif, *.jpg, *.png, *.zip, *.tar.gz
- After the submission, the files are post-processed:
  - File types not specified above are deleted.
  - Only the body part of every HTML file is kept.
  - All the format/style/css information, like `style=..`, `class=..` are removed from the body part.
- If you decide to use PDF documents, use the `index.html` to include links to them.
- There are three states of the submission:
  - Submitted: The author and the chief editor receive a notification mail. The submission is only accessible for the chief editor to accept the submission.
  - Opened for review: The submission is open for users to post their comments and reviews. After that the chief editor can accept the paper.
  - Accepted: The submission is open for everybody.

11.4 Datafiles

Below we suggest a format for linear dynamic systems. The development of a scalable data format for time-dependent and nonlinear dynamic systems is considered to be a challenge to be solved later on. At present, for time-dependent and nonlinear systems, we suggest to use the Dynamic System Interchange Format described in Chapter 12.

All the numerical data for the collection can be considered as a list of matrices, a vector being an $m \times 1$ matrix. As a result, first one should follow a naming convention for the matrices, second one should write each matrix in the format described below.

11.4.1 Naming Convention

For the two cases of a linear dynamic system of the first and second orders, the naming convention is as follows

$$\begin{aligned} E\dot{x} &= Ax + Bu \\ y &= Cx + Du \end{aligned} \tag{11.1}$$

$$\begin{aligned} M\ddot{x} + E\dot{x} + Kx &= Bu \\ y &= Cx + Du \end{aligned} \tag{11.2}$$

An author can use another notation in the case when the convention above is not appropriate. This should be clearly specified in the benchmark document.

11.4.2 Matrix Format for Linear Systems

A matrix should be written in the the Matrix Market format [BPR96].

A file with a matrix should be named as *problem_name.matrix_name*.

If there is no file for a matrix, it is assumed to be identity for the M, E, K, A matrices and 0 for the D matrix.

All matrix files for a given problem should be compressed in a single zip or tar.gz archive.

11.5 Acknowledgments

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References

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