MAX PLANCK INSTITUTE
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CSC

COMPUTATIONAL METHODS IN
SYSTEMS AND CONTROL THEORY

Model Order Reduction for Gas and Energy Networks

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Outline

1. Design Principles
2. `morgen` Framework
3. Outlook

morgen[1]

- Test, benchmark and compare
- data-driven (time-domain)
- model reduction techniques
- for (nonlinear) gas networks
- modularly and configurably.
- OCTAVE & MATLAB compatible.

[1] **M**odel **O**rder **R**eduction for **G**as and **E**nergy **N**etworks

Modules

- Models
- Solvers
- Decouplers
- Reductors
- Networks & Scenarios
- Other

Models

- Friction[2]
- Compressibility[3] (WIP)
- Gravity[4] (WIP)
- Linearized[4] (WIP)
- Descriptor
- Herty Approximation[4]

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[2] S. Grundel, L. Jansen, N. Hornung, T. Clees, C. Tischendorf, and P. Benner. **Model order reduction of differential algebraic equations arising from the simulation of gas transport networks**. In Progress in Differential-Algebraic Equations, Differential- Algebraic Equations Forum, pages 183–205. Springer Berlin Heidelberg, 2014.

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Solvers

- IMEX-1[5] (First Order Implicit-Explicit Runge-Kutta)
- IMEX-2[6] (Second Order Implicit-Explicit Runge-Kutta)
  - Implicit: Passive Runge-Kutta[7] (DIRK-2)
  - Explicit: Strong Stability Preserving Runge-Kutta[8] (SSP-2)
- Generic
  - MATLAB: ode15s[9]
  - OCTAVE: ode2r[10]

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[9] `https://mathworks.com/help/matlab/ref/ode15s.html`

[10] `https://octave.sourceforge.io/odepkg/function/ode2r.html`

Decouplers

- Linear(ized)[11]
- Quadratic[12] (WIP)
- Generic Nonlinear (WIP)

[11] G. Ali, N. Banagaaya, W.H.A. Schilders, and C. Tischendorf **Index-Aware Model Order Reduction for Linear Index-2 DAEs with Constant Coefficients**. SIAM Journal on Scientific Computing 35(3): A1487–A1510, 2013.

[12] N. Banagaaya, P. Benner, L. Feng, P. Meuris, and W. Schoenmaker. **An index-aware parametric model order reduction method for parameterized quadratic differential-algebraic equations**. Applied Mathematics and Computation, In Press:1–16, 2017.

Reductors

In structured and unstructured variants:

- Proper Orthogonal Decomposition[13] (POD)
- Dynamic Mode Decomposition[14] (DMD-Galerkin)
- Empirical Balanced Truncation[15]
- Empirical Cross Gramian[16] (*)
- Empirical Non-Symmetric Cross Gramian[17]

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[13] P. Holmes, J.L. Lumley, G. Berkooz, and C.W. Rowley. **Turbulence, coherent structures, dynamical systems and symmetry**. Cambridge Monographs on Mechanics. Cambridge University Press, Cambridge, 2012.

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Networks & Scenarios

- Procedural pipeline
- Forked network
- Diamond network
- AzeJ07[18] (WIP)
- GruHKetal13[19]
- GruHJetal14[20]
- GruHR16[4] (WIP)
- GasLib-582[21] (WIP)

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[18] T.P. Azevedo-Perdicoulis and G. Jank. **Modelling Aspects of Describing a Gas Network Through a DAE Ssystem**. In IFAC Proceedings Volumes 40(20): 40–45, 2007.

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[21] http://gaslib.zib.de

Other

- Tests for verification and validation
- Plain text intermediary formats:
  - Network (`csv`)
  - Scenario (`ini`)
- Configuration:
  - Friction formula
  - Compressibility formula
  - etc.
- Utility library

Upcoming

- `json` network parser
- Alternative Discretizations
- More networks:
  - External compressors[18]
  - Internal compressors (???)
- More data-driven MOR methods:
  - balanced POD[22] (bPOD)
  - input-output DMD[23] (ioDMD)
- Visualization

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Overall

- Basic functionality is ready.
- Advanced features in development.
- Reusability is essential.

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