Energy based mathematical modeling, simulation and control of digital twins in energy networks

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Volker Mehrmann is SIAM and AMS Fellow, has held an ERC Advanced Grant and also was member of the ERC Mathematics Panel. He is editor of several journals in numerical analysis and editor-in-chief of Linear Algebra and its Applications. His research interests are in the areas of numerical mathematics/scientific computing, applied and numerical linear algebra, control theory, the theory and numerical solution of differential-algebraic equations, and in energy based mathematical modeling.

Sumário

The concept of building digital twins or real physical systems is an important research topic in most areas of science and engineering. Most real world dynamical systems consist of subsystems from different physical domains, modelled by partial-differential equations, ordinary differential equations, and algebraic equations, combined with input and output connections. To deal with such complex systems, in recent years the class of dissipative port-Hamiltonian (pH) descriptor systems has emerged as a very successful mathematical modeling paradigm. The main reasons are that the network based interconnection of pH systems is again pH, Galerkin projection in PDE discretization and model reduction preserve the pH structure and the physical properties

are encoded in the geometric properties of the flow as well as the algebraic properties of the equations. Furthermore, dissipative pH systems form a very robust representation under structured perturbations and directly indicate Lyapunov functions for stability analysis. Another advantage of energy based modeling via pH systems is that each separate model of a physical system can be a whole model catalog from which models can be chosen in an adaptive way within simulation and optimization methods.

We discuss the use of the model class of constrained pH systems in the construction of digital twins and show how many classical real world mathematical models can be formulated in this class. We illustrate the results with some real world examples from gas transport and district heating systems and point out emerging mathematical challenges.

Bibliografia

[1] H. Dänschel, V. Mehrmann, M. Roland, and M. Schmidt, *Adaptive Nonlinear Optimization of District Heating Networks Based on Model and Discretization Catalogs*, SeMA Journal https://doi.org/10.1007/s40324-023-00332-6, 2023.

[2] S.-A. Hauschild, N. Marheineke, V. Mehrmann, J. Mohring, A. Moses Badlyan, M. Rein, and M. Schmidt, Port-Hamiltonian modeling of district heating networks, Progress in Differential-Algebraic Equations II, 333-355, DAE Forum, Springer Verlag, 2020.

[3] V. Mehrmann, M. Schmidt, and J. Stolwijk, *Model and Discretization Error Adaptivity within Stationary Gas Transport Optimization*, Vietnam Journal of Mathematics, DOI: 10.1007/s10013-018-0303-1, Vol 46, 779–801, 2018.

[4] V. Mehrmann and B. Unger, *Control of port-Hamiltonian differential-algebraic systems and applications*, Acta Numerica, 395–515, 2023. doi:10.1017/S0962492922000083