

M13 : Port-Hamiltonian Systems: from Geometric Network Modeling to Control

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Course description:

First we start with the basic concepts of port-based network modeling, where complex lumped-parameter multi-physics systems are systematically modeled as networks of ideal components linked by energy-flow. We show how this immediately leads to a differential equation representation that is in generalized Hamiltonian form, including the standard conservative Hamiltonian systems based on the exchange of energy between different energy storages; e.g., in the mechanical domain between potential and kinetic energy. Furthermore, we discuss how the port-Hamiltonian representation leads to other useful representations such as the Brayton-Moser equations. We show how port-Hamiltonian models not only reflect the energy flow in the system, but also capture the other basic physical conservation laws, such as conservation of momentum or charge. This will be amply illustrated on a number of applications stemming from mechanics, mechatronics, hydraulic systems, MEMS, and power systems. We also show how distributed-parameter (partial-differential equation) components are incorporated in this broadly applicable modeling approach to nonlinear multi-physics systems.

In the second part of the course we show how this port-Hamiltonian framework serves as a starting point for deriving control strategies that explicitly take into account the physical properties of the nonlinear system. The two main approaches are 'control by interconnection' for port-Hamiltonian systems, and the related approach of 'interconnection-damping assignment' where control is used to obtain a 'virtual' physical system with desired properties. We discuss how these approaches can be applied to multi-physics systems incorporating infinite-dimensional components such as, e.g., power systems with transmission lines and hydraulic systems with fluid dynamic components.



Arjan van der Schaft received the undergraduate, graduate, and Ph.D. degrees in Mathematics from the University of Groningen, The Netherlands. In 1982 he joined the University of Twente, where he was appointed as a full professor in 2000. In 2005 he returned to Groningen as a full professor in Mathematics.

He has served as Associate Editor for Systems & Control Letters, Journal of Nonlinear Science, SIAM Journal on Control, and the IEEE Transactions on Automatic Control. Currently he is Associate Editor for Systems and Control Letters, Journal of Geometric Mechanics, and Editor-at-Large for the European Journal of Control.

He is (co-)author of a number of books, including Nonlinear Dynamical Control Systems (1990, with H. Nijmeijer), L₂-Gain and Passivity Techniques in Nonlinear Control (1996, 2000), and An Introduction to Hybrid Dynamical Systems (2000, with J.M. Schumacher).

Recurrent theme in his research is the modeling, analysis and control of open dynamical systems. Present focus is on network modeling and analysis of complex systems and their geometric formulation as open Hamiltonian systems, the compositional modeling, analysis and control of systems with interacting continuous and discrete dynamics, and their applications in multi-physics systems, embedded systems and systems biology. See <http://www.math.rug.nl/~arjan/> for further info.

Arjan van der Schaft is Fellow of the IEEE.



Dimitri Jeltsema received the B.Eng. degree in electrical engineering from the Rotterdam University of Applied Science, The Netherlands, and the M.Sc. degree in systems and control engineering from the University of Hertfordshire, United Kingdom in 1996 and 2000, respectively. In May 2005 he received the Ph.D. degree (with honors) from Delft University of Technology, The Netherlands. Until 2007 he has been a post doctoral researcher and lecturer at the Delft Center for Systems and Control. Currently he is an assistant professor at the Mathematical Systems Theory Group of the Delft Institute of Applied Mathematics. His research interests include modeling, analysis and control of nonlinear circuits and systems. See <http://www.dcsc.tudelft.nl/~jeltsema/> for further info.