Seminar in Autumn Semester 2024:

Port-Hamiltonian Systems: Mathematical Analysis

Lecturer	: Prof. Ralf Hiptmair, D-MATH
Venue	: HG E 21
Time	: Monday, 16:15 - 18:00
	: Thursday, 16:15 - 18:00
Language	: English
Prep meeting	: Monday, September 16, **17:15**, HG E 21
	: optional ZOOM Meeting ID: 654 8097 8647
Individual tutoring	: Tuesday
First session	: Monday, October 21
Contact	: R. Hiptmair, hiptmair@sam.math.ethz.ch
Prerequisites	: Knowledge of linear algebra and ordinary differential equations
Audience	: MSc & 3rd year BSc Students of Mathematics

Description:

Port-Hamiltonian provide a mathematical framework for the modeling of complex (multi-physics) systems, of their dynamical behavior, for understanding their stability and effective control. They are based on geometric structure and represent a generalization of Hamiltonian systems towards open systems. The building blocks of port-Hamiltonian systems are thought to interact by exchanging energy. So the main focus of port-Hamiltonian modeling is on accurately representing the flow, storage, and dissipation of energy.

Port-Hamiltonian models are ubiquitous nowadays, used in areas like mechanics, fluid dynamics, thermodynamics, and (electric) circuits. They play a big role in modern control theory and are a highly active field of theoretical and applied research.

Pre-Requisite Knowledge:

Familiarity with ordinary differential equations and foundations of differential geometry (manifolds, vector fields, differential forms).

Presentations:

Each topic defined by one or more research articles should be covered in a roughly 60 minute presentation, based on prepared slides, and, maybe, short explanations on the blackboard or tablet. The slides should be made available as PDF beforehand (Upload to polybox or send by email, filename `Topic_<NO>.pdf`.)

The seminar will comprise up to 12 student presentations of a duration of about 60 minutes. They should be held by teams of three with members presenting in turns in random order.

Guidelines for preparing slides:

- Reduce text
- Use pictures and visual elements
- Use boxes and colors for highlighting
- Incrementally reveal content through overlays

Guidelines for structuring a talk:

- The presentations should be example-driven
- Exhibit core ideas by simplifying
- Repeat content: the audience cannot remember details from earlier slides
- Connect your presentation to previous talks.
- Zig-zag plan of talks: return to big picture and main objective occasionally.
- Keep a focus: discard marginal content

Quizz:

Participants of the seminar will be asked questions about the previous presentations at the beginning of each session.

Available topics:

1. Hamiltonian systems [5] (Elementary introductory lecture). See also Sections VI.1, VI.2, and VI.5 of [6].
2. From Hamiltonian Systems to Poisson Geometry [9] (Introduction based on concepts from differential geometry). See also [6, VII.2]
3. Bond Graph Modeling [3, Appendix], [2] (Elementary engineering style introduction)
4. Hamiltonian formulation of network dynamics [7, 8]

5. Network modeling of physical systems [12], [10, Chapter 5].
6. Port-Hamiltonian systems [10, Sections 2.1-2.6]
7. Input-state-output PHS [10, Chapter 4]
8. Port-Hamiltonian systems on manifolds [10, Chapter 3], [4]
9. Port-Hamilotian systems on graphs [10, Chapter 12], [14]
10. PHS description of fluids [11]
11. Distributed PHS [13], [10, Chapter 14]
12. TBD

Speakers and dates for presentations:

- Team 1:
  - Aron KARAKAI
  - Isaak BUTZ
  - Nicolas GUBSER
- Team 2:
  - Xiwei WANG
  - Yannick DE BRUIJN
  - David BLAETTLER
- Team 3:
  - Sauditya JAISWAL
  - Luis BUNGERT
- Team 4:
  - Nicolas BACHMANN
  - Jan Höhner

Date, Time	Room	**Team**	Topic #	Tutoring slot
Mon Oct 28, 16:15 - 18:00	HG E 21	**2**	1	Oct 24, 16:15 (ZOOM)
Thu Oct 31, 16:15 - 18:00	HG F 26.1	**3**	2	Oct 28, 18:00
Mon Nov 4, 16:15 - 18:00	HG E 21	**1**	3	Oct 31, 18:00
Thu Nov 7, 16:15 - 18:00	HG F 26.1	**4**	4	Nov 5, 18:15
Mon Nov 11, 16:15 - 18:00	HG E 21	**2**	5	Nov 7, 18:00
Thu Nov 14, 16:15 - 18:00	ML J 37.1	**3**	6	Nov 11, 18:00
Mon Nov 18, 16:15 - 18:00	HG E 21	**1**	7	Nov 14, 18:00
Thu Nov 21, 16:15 - 18:00	ML J 37.1	**4**	8	Nov 18, 18:00
Mon Nov 25, 16:15 - 20:00	HG E 21	**2**	9	Nov 21, 18:00
Mon Dec 16, 16:15 - 18:00	HG E 21	**1**	10	Dec 12, 18:00

The dates and times for the tutoring meeting are tentative. Those can also be conducted online on other dates.

References

[1] A. Bartel, M. Clemens, M. Günther, B. Jacob, and T. Reis, *Port-hamiltonian systems modelling in electrical engineering*, 2023.

[2] J. F. Broenink, *Introduction to physical systems modelling with bond graphs*, 2000.

[3] D. Crolla and B. Mashadi, *Vehicle Powertrain Systems: Integration and Optimization*, Wiley, 2012.

[4] M. Dalsmo and A. van der Schaft, *On representations and integrability of mathematical structures in energy-conserving physical systems*, SIAM J. Control Optim., 37 (1999), pp. 54–91.

[5] E. Haierer, *Hamiltonian systems*. Lecture at TU Munchen, 2010.

[6] E. Hairer, C. Lubich, and G. Wanner, *Geometric numerical integration*, vol. 31 of Springer Series in Computational Mathematics, Springer, Heidelberg, 2 ed., 2006.

[7] B. Maschke, A. van der Schaft, and P. Breedveld, *An intrinsic hamiltonian formulation of the dynamics of lc-circuits*, IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications, 42 (1995), pp. 73–82.

[8] B. M. Maschke, A. J. van der Schaft, and P. C. Breedveld, *An intrinsic Hamiltonian formulation of network dynamics: nonstandard Poisson structures and gyrators*, J. Franklin Inst., 329 (1992), pp. 923–966.

[9] S. W. Musser, *From hamiltonian systems to poisson geometry*. University of Chicago Lecture Notes, 2015.

[10] A. van der Schaft and D. Jeltsema, *Port-Hamiltonian Systems Theory: An Introductory Overview*, Now Publishers, Delft, NL, 2014.

[11] A. Van der Schaft and B. Maschke, *Fluid dynamical systems as hamiltonian boundary control systems*, in Proceedings of the 40th IEEE Conference on Decision and Control (Cat. No.01CH37228), vol. 5, 2001, pp. 4497–4502 vol.5.

[12] A. van der Schaft, B. Maschke, and R. Ortega, *Network modelling of physical systems: a geometric approach*, in Advances in the control of nonlinear systems (Murcia, 2000), vol. 264 of Lect. Notes Control Inf. Sci., Springer, London, 2001, pp. 253–276.

[13] A. J. van der Schaft and B. M. Maschke, *Hamiltonian formulation of distributed-parameter systems with boundary energy flow*, J. Geom. Phys., 42 (2002), pp. 166–194.

[14] ——, *Port-Hamiltonian systems on graphs*, SIAM J. Control Optim., 51 (2013), pp. 906–937.

Link for accessing literature and slides: `https://polybox.ethz.ch/index.php/s/QuAYObBH1b6B0Lz`, password: `PHS_HS24`