PhD Thesis in Automatic Control
LABEX ACTION

Smart Boundary Control of VibroAcoustic and Elastodynamic Systems
-
A Distributed Port Hamiltonian Approach

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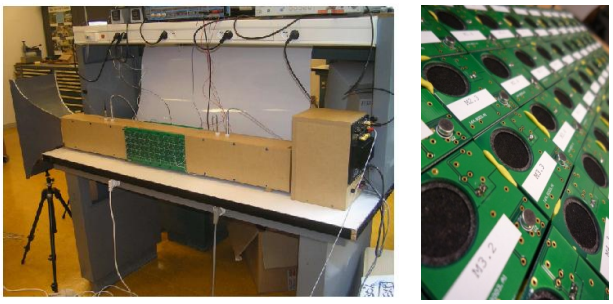
Detailed description: The modeling of physical systems based on the representation of intrinsic energy exchanges between different energetic domains allows a modular description of their (eventually complex) dynamic behaviour. In this context, the port-Hamiltonian framework represents a powerful modeling and control tool. Port-Hamiltonian systems link the physical energy of a system and its dynamic behaviour through the definition of a geometric structure, named Dirac structure. This geometric structure, which arises in the modeling step, is instrumental for the stability analysis and the control design. In the case of non-linear or distributed parameter systems, the structure is not only instrumental, but also fundamental to study the solutions in a systematic manner. Even though the formalism is not new [1], it has only been extended to distributed parameter systems in 2002 [2]. The complete parametrization of linear distributed port Hamiltonian systems controlled at the boundaries over a 1D spatial domain, as well as the study of the existence of solutions and stability properties, can be found in [3, 4, 5]. These results have recently motivated the extension of passivity based control techniques to the infinite dimensional case [6, 7].

The aim of the thesis is to propose passivity based control strategies for the acoustic or elastic wave attenuation at the output of 2D and 3D acoustic systems [9]. The experimental set-up of Fig. 1 will be available to validate the developed control approaches. A first approach will use a distributed dissipative port-Hamiltonian representations of the distributed parameter model for the control synthesis. In a second instance, the derivation of a finite dimensional port-Hamiltonian approximation based on k-forms [10] will be developed and used for the control design. In both cases, special attention will be given to the reduction/approximation scheme and the fact that the control will account for the structure of the distributed network of actuators/sensors. More specifically, the robustness of the controllers will be investigated with respect to the structured model error of the finite dimensional approximation of the infinite-dimensional port-Hamiltonian system.

Working context : The Ph.D. takes place in the frame of the french ANR sponsored research projects LABEX ACTION (http://www.labex-action.fr/) and HAMECMOPSYS (https://hamecmopsys.ens2m.fr/). The research activities will be developed at the AS2M department in collaboration with the Mec'Appli department in FEMTO-ST, Besançon, France (http://www.besancon.fr). The candidate will have to collaborate with foreign researchers involved in the aforementioned projects (University of Twente, The Netherland, University of Bologne, Italy).The candidate is expected to valorize his research work by submitting research papers to high level conferences and journals, as well as actively participating in local and international seminars, workshops and conferences.



(a) Acoustic system (b) Actuator

FIG. 1: *Experimental acoustic system*

[1] B. Maschke, and A. van der Schaft Port controlled Hamiltonian systems: modeling origins and system theoretic properties. *In Proceedings of the 3rd IFAC Symposium on Nonlinear Control Systems, NOLCOS'92*, Pages 282-288. Bordeaux, France, 1992.

[2] A. J. van der Schaft and B. Maschke. Hamiltonian formulation of distributed-parameter systems with boundary energy flow *Journal of Geometry and Physics*Vol. 42, Pages: 166–194, 2002

[3] Y. Le Gorrec, H. Zwart and B. Maschke. Dirac structures and Boundary Control Systems associated with Skew-Symmetric Differential Operators. *SIAM Journal on Control and Optimization*, Vol. 44(5), Pages: 1864–1892, 2005.

[4] J. A. Villegas, H. Zwart, Y. Le Gorrec, B. Maschke. Exponential Stability of a Class of Boundary Control Systems. *IEEE Transactions on Automatic Control*- Vol. 54(1), Pages: 142–147, January 2009.

[5] H. Zwart, Y. Le Gorrec, B. Maschke and J. Villegas. Well-posedness and regularity of hyperbolic boundary control systems on a one-dimensional spatial domain. *ESAIM Control, Optimisation and Calculus of Variations,* Vol. 16, Pages: 1077–1093, 2010.

[6] H. Ramirez, Y. Le Gorrec, A. Macchelli and H. Zwart. Exponential Stabilization of Boundary Controlled Port-Hamiltonian Systems with Dynamic Feedback *Automatic Control, IEEE Transactions on* vol.PP, no.99, pp.1,1, doi: 10.1109/TAC.2014.2315754. (In press)

[7] Y. Le Gorrec, A. Macchelli, H. Ramirez and H. Zwart. Energy shaping of boundary controlled linear port Hamiltonian systems. *The 19th IFAC World Congress* Cape Town, South Africa, August, 2014.

[8] Y. Le Gorrec and D. Matignon. Coupling between hyperbolic and diffusive systems: a port-Hamiltonian formulation *European Journal of Control* Vol. 19 (6), Pages 505–512, 2013.

[9] P. David, M. Collet and J-M. Cote. Experimental implementation of acoustic impedance control by a 2D network of distributed smart cells. *Smart Materials and Structures* Vol. 19 (3), Pages 035028, 2010.

[10] A. van der Schaft and B. Maschke. Port-Hamiltonian Systems on Graphs *SIAM Journal on Control and Optimization* Vol. 51 (3), Pages 906-937, 2013.

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