Stabilization of a class of port-Hamiltonian systems using saturated controllers

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Abstract

The port-Hamiltonian (PH) framework has been extensively used to model physical systems. One of the main advantages of this modeling approach is that it provides a systematic procedure to obtain mathematical models that capture the nonlinear phenomena and preserve conservation laws present in physical systems [1]. Additionally, in this framework, the roles of the interconnection pattern, the dissipation, and the energy are underscored. Thus, a natural way to control passive systems is to design controllers that give the desired shape to the energy of the closed-loop system. This process is known as energy-shaping and it is the main idea of several passivity-based control (PBC) approaches.

While PBC techniques have been proved to be effective to solve the stabilization problem of physical systems [2], [3], some important issues, that might arise during the implementation of these controllers, are not addressed by these techniques, e.g., the lack of sensors to measure some variables or constraints in the actuators. Indeed, these are pervasive problems in nonlinear control, therefore, finding a solution to them is paramount from a practical perspective.

In this work, we propose a PBC approach that deals with the problem of set-point regulation for a class of physical systems. Moreover, this approach has the following appealing features

- It obviates the necessity of solving partial differential equations, which, in general, are one of the main constraints of the PBC techniques.
- The controllers derived from this approach are saturated, and the saturation limits can be straightforwardly adjusted.
- The control design only requires a partial measurement of the state. Particularly for mechanical systems, it is not necessary to measure the velocities (momenta).
- It is possible to include an integral-like term that ensures the convergence of the steady-state error to zero.

The proposed PBC approach follows the ideas previously reported in [4] and [5]. As proposed in the latter, the control design requires the definition of a "virtual state" whose dynamics are designed in such a way that it is possible to inject damping in coordinates that cannot be measured. Moreover, a direct extension of the results reported in [4] ensures the saturation of the control signal. This is sometimes required to avoid malfunctions in the actuators of physical systems.

With the aim of presenting our results, we, first, provide a characterization of the PH systems for which the proposed PBC approach is suitable. Towards this goal, we provide assumptions that can be verified in a systematic way. Then, we proceed with the control design, and we provide the stability analysis of the closed-loop system, which is carried out using passivity arguments and Lyapunov theory. Finally, we illustrate the applicability of the technique through the experimental results obtained for a planar robot with two links and flexible joints.

References

[1] Duindam, V., Macchelli, A., Stramigioli, S., & Bruyninckx, H. (Eds.). (2009). *Modeling and control of complex physical systems: the port-Hamiltonian approach*. Springer Science & Business Media.

[2] Ortega, R., Perez, J. A. L., Nicklasson, P. J., & Sira-Ramirez, H. J. (2013). *Passivity-based control of Euler-Lagrange systems: mechanical, electrical and electromechanical applications*. Springer Science & Business Media.

[3] van der Schaft, A. J. (2000). *$\mathscr{L}_2$-gain and passivity techniques in nonlinear control*. London: Springer.

[4] Borja, P., Cisneros, R., & Ortega, R. (2016). A constructive procedure for energy shaping of portHamiltonian systems. *Automatica*, 72, 230-234.

[5] Dirksz, D. A., & Scherpen, J. M. A. (2013). On tracking control of rigid-joint robots with only position measurements. *IEEE Transactions on Control Systems Technology*, 21(4), 1510-1513.