Discussion on: “Feedback Stabilization of Infinite-Dimensional Linear Systems with Constraints on Control and its Rate”

Fouad Mesquine1,*, Fernando Tadeo2,**, Teresa Alvarez2,***

1 EACPI, Univ. Cadi Ayyad, Faculty of Science Semlalia, Marrakech, Morocco;
2 Departamento de Ingenieria de Sistemas y Automatica, University of Valladolid, Valladolid, Spain

This discussion addresses some aspects of the paper “Feedback Stabilization of Infinite-Dimensional Linear Systems with Constraints on Control and its Rate”, which investigates the design of stabilizing controllers for a certain class of systems with constrained controls. In particular, in this discussion we emphasize the importance of considering simultaneously constraints on the magnitude and rate on the control signal, by providing a review of practical examples published in the literature. It is also argued that approaches based on the Positive Invariance concepts, such as the one presented in the paper, are the very adequate for this problem, as they give a simple control structure, and make it possible to consider that many real constraints are significantly nonsymmetric by nature. Moreover, it is also emphasized in this discussion how treating infinite-dimensional systems makes the proposed technique general, and interesting for real systems that contain partial differential equations or delays.

1. Systems with Constraints

It is well known that most real plants involve bounded variables, particularly bounded control signals, with these bounds arising from physical constraints. These constraints must be considered during controller design, as they have a significant destabilizing effect [3]. Although the design of controllers for systems with constraints have been extensively studied (see, for example, [5], [11], [13]), most of these works concentrated on symmetric saturation of the controller, that is, only the magnitude of the control signal is bounded, and these bounds are assumed to be symmetric. We can cite in this context [2], that considered asymmetric constraints, but only on the magnitude (see references therein for list of works on asymmetric saturations).

However, in many practical systems, the rate of change of the control variable is also limited. This is important to consider when designing the controller, because these limits can arise from physical constraints that, if violated, could mean the loss of stability of the process [12]. Some examples of practical systems with constraints on the magnitude and rate are the following:

- Aerospace systems: [4], [7]
- Wastewater treatment: [25]
- Chemical Processes: [18], [26]
- Climatic variables inside buildings: [21]
- Mechatronics: [26]
- Automatic drug dosing: [20]
- Sterilization processes: [24]
- High energy physics: [22], [6]

From a practical point of view, probably the most successful approach that makes possible to consider simultaneously magnitude and rate constraints is the Predictive Control approach [8], [15], that has been extensively tested in practical situations where constraints on the control signal are important [21], [18], [26], [20]. Unfortunately the implementation of Predictive Controllers is complex, which makes the Positive Invariance approach used in the paper under discussion specially attractive as it gives a simple method to calculate simple-to-implement
controllers, even for the class of infinite-dimensional systems considered in this paper. Moreover, the Positive Invariance approach makes it possible to consider nonsymmetric constraints. These nonsymmetric constraints are very frequent in practical control problems, not only for the magnitude bound [26], [20], but also for the rate constraint [25], [24], [6].

2. Infinite-Dimensional Systems

Infinite dimensional systems (IDS) appear naturally in models of systems affected by delays, with distributed parameters, etc. The most commonly used approach for controller design is to approximate the IDS by a finite-dimensional system (for example, approximating the Partial Differential Equations by Ordinary Differential Equations –ODEs-) and then apply standard finite-dimensional controller design methods. The main drawbacks [14] are that the dimension of the ODEs can be high, resulting in complex controllers and high computational cost, and that ODEs do not represent exactly IDS, so relevant behaviors are missed. Moreover, this approach hides the underlying structure and dynamics of the optimal controller for the IDS, with a loss in understanding, and efficiency (e.g., see discussion by [1] and references therein). Thus, it is worth investigating specific methods for IDS (a good introduction can be found in [10]), such as the one proposed in the paper under discussion, which deals directly with IDS under the mild assumption of operator’s compactness. Hence, the extension of recently established results [16], [17] for finite-dimensional systems to IDS is of great relevance. Using projection and resolvent tools makes possible this extension, first in the discrete-time case, and then in the continuous-time case. However, further work needs to be done, following this work, to wholly extend to IDS, the finite-dimensional methodology to find stabilizing regulators satisfying all constraints. Answering this open question may, in fact, give more importance to the results established up to now.

Acknowledgments

This work is funded by mcyt-CICYT project DPI2004-07444-C04-02 and Morocco-Spain AECl research project A/7882/07.

References

9. Chen PC. Robust output feedback control for saturated linear systems with magnitude and rate constraints. Proceedings of SICE Annual Conference, 2405–2410.