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Discussion on “On preserving passivity in sampled-data linear systems”

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I. Discussion on the Contributions

The goal of this paper is to introduce a methodology to preserve the passivity of a continuous time system under discretization. The authors define a new output that allows to preserve the passivity of the continuous system in its discrete counterpart with the same storage function. First the authors give a general definition of the output and then they specialize it for linear systems.

The result proposed in the first part of the paper is very interesting and very general. The authors, generalizing the original work done in [6], consider dynamical systems whose passivity is preserved without adding any external action (e.g. damping as in [4], [2]) but simply recognizing that it is necessary to define a new discrete output. This approach is similar in the spirit to the one proposed in [6] but it is more general since in the paper by Costa-Castelló and Fossas there is no restriction on the structure of the dynamical systems to be sampled while in [6] the authors focuses on port-Hamiltonian systems since their interest was mainly on the interactive control of robotic systems.

In the second part of the paper the authors specialize the general result obtained in the first part to linear systems. This part is less interesting than the first one since the results reported in Sec.4 can be easily derived directly from Eq.(11) and the authors go too much into the mathematical details. The LMI analysis doesn't provide many more information than what is proposed in Sec. 4.1, Proposition 4 is just another way to prove that choosing the output reported in Eq.(11) allows to preserve passivity under sampling. We do not see any meaningful characterization here.

In summary, we believe that the result provided in Sec. 3 is of great interest for the control community but that the authors should have worked on an example of digital passivity based control rather than on such a too detailed extension of the result to the linear case.

II. Discussion on the impact of the contributions

We see two interesting directions that can be considered for future investigations.

The first one deals with the digital implementation of passivity based controllers. Several passivity based control strategies have been developed in the literature (see e.g.[7]) but usually the issues related to their digital implementation are not taken into account.

It is true that some passivity based control actions (e.g. those based on the so-called damping injection, [7]) can be implemented digitally without any modifications.

Nevertheless, a very important class of passivity based controllers, are based on the so-called *energy shaping* and they need to be properly modified for being implemented digitally. We believe that in this framework the approach developed in the paper can be very helpful. In fact, the starting point of energy shaping approaches is usually a passive plant to which a controller that shapes the storage function of the plant in order to make it a candidate Lyapunov function with a minimum in a desired configuration is interconnected . Thus, using the result proposed in the paper, it is possible to obtain a sampled data plant which is passive with the same storage function as that of the original plant and to which a digital controller can be interconnected. In this way the digital energy shaping controller has to shape exactly the same energy function of the original system and, presumably, using the discrete version of the steps required for building the continuous energy shaping controller, it should be possible to build its discrete counterpart. The main issue to address within this framework is the structure of the dynamical equations of the plant. In fact, usually energy shaping control strategies assume that the plant has a particular structure (e.g.: Hamiltonian [7] or Lagrangian[3]). When replacing the continuous plant with its sampled data version the state vector field is replaced with its integral, as it can be seen in Eq.(8), and this can lead to a loss of the structure of the continuous state equation. This could make the control problem significantly more difficult. In fact, because of the loss of structure, it could be necessary to make significant changes to the steps required to build the energy shaping controller in continuous time for building the discrete controller that has to shape the *same* energy function in discrete time.

The second possible direction for future research is in the field of the control over networks where the plant and the controller are interconnected by means of a communication network [8]. A major problem for these control systems is the destabilizing effect of the delay in the communication between the controller and the plant. This problem has been widely studied in the literature and several control strategies have been proposed. The need of using *digital* packet switched networks (e.g. Internet) as communication channels is increasing due to their cheapness and wide diffusion.

In the case that the plant and the controller are passive systems (i.e. in case of passivity based control over networks), scattering based communication channels, widely used in telerobotics, can be used to enable a passive exchange of information independently of the communication delay. In this way, it is possible to design passive controllers that allow to regulate a passive plant in a desired point independently of any constant delay [1], [5]. In [6], within the field of bilateral telemanipulation over digital network, discrete scattering based communication channels have been defined and a strategy for allowing a passive exchange of information independently of the variability of the communication delay and of the possible loss of packets has been proposed. We believe that it is possible to combine the results defined in Sec. 3 with those presented in [6] to build a passivity based energy shaping over networks that allows to stabilize a passive system in a desired configuration by shaping its storage function by a discrete controller that exchanges data with the plant over a digital network; the stabilization process would be achieved independently of any, possibly variable, delay and of possible loss of information in the communication. In fact, given a passive plant to stabilize, using the results presented in Sec. 3, it is possible to obtain a passive sampled data system that can be interconnected to the digital scattering based communication channel proposed in [6]. The overall system (sampled data plant+communication channel) is passive in a discrete sense (independently of any communication delay, possibly variable, and of loss of packets) and it can be interconnected, through the channel, to a discrete passive controller whose role is to shape the energy of the overall system in such a way that the plant is taken in the desired configuration. The way in which to design such a discrete controller is an open issue but some preliminary results can be found in [5].

REFERENCES

[1] T. Matiakism, S. Hirche, and M. Buss. A novel input-output method to stabiliza networked control systems independent of delay. In *Proceedings of the Symposium on Mathematica Theory of Networks and Systems*, Kyoto, Japan, July 2006.

[2] B.E. Miller, J.E. Colgate, and R.A. Freeman. Guaranteed stability of haptic systems with nonlinear virtual environnments. *IEEE Transactions on Robotics and Automation*, 16(6):712–719, December 2000.

[3] R. Ortega, A. Loria, P.J. Nicklasson, and H. Sira-Ramirez. *Passivity-based Control of Euler-Lagrange Systems*. Springer-Verlag, London, UK, 1998.

[4] J.H. Ryu, D.S. Kwon, and B. Hannaford. Stability guaranteed control: time domain passivity approach. *IEEE Transactions on Control Systems Technology*, 12(6):860–868, November 2004.

[5] C. Secchi and C. Fantuzzi. Energy shaping over networks for mechanical systems. In *Proceedings of IEEE Conference on Decision and Control*, New Orleans, LA, USA, December 2007.

[6] S. Stramigioli, C. Secchi, A.J. van der Schaft, and C. Fantuzzi. Sampled data systems passivity and discrete port-hamiltonian systems. *IEEE Transactions on Robotics*, 21(4):574–587, 2005.

[7] A.J. van der Schaft. *L_2-Gain and Passivity Techniques in Nonlinear Control*. Communication and Control Engineering. Springer Verlag, 2000.

[8] T.C. Yang. Networked control systems: a brief survey. *IEE Proceedings on Control Theory and Applications*, 153(4), 2006.