16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Proposal of a control hardware architecture for implementation of fractional-order controllers

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Abstract: This paper presents a proposal of a control hardware architecture for the implementation of integer-order (IO) and fractional-order (FO) controllers. In particular, the design and experimental validation of the FO controllers implemented in several control technologies are applied to a temperature laboratory setup in order to demonstrate the effectiveness of the proposed hardware architecture. Some comments relating to industrial practice are offered in this context.

Keywords: fractional-order controllers, control hardware, experimental equipment

1. Introduction

In spite of all the advances in process control over the past several decades, the proportional integral derivative (PID) controller remains to be certainly the most extensive option that can be found on industrial control applications and have become an industrial standard for process control, see [1].
While more powerful control techniques are readily available, the transparency and relative simplicity of the PID control mechanism, the availability of a large number of reliable and cost-effective commercial PID modules, and their widespread acceptance by operators are among the reasons of its success and popularity, see [2].
Over the last decades, the emergence of fractional calculus (FC) has made possible a great deal of academic and industrial effort focused on the transition from classical models and controllers to those described by differential equations of non-integer order. Thus, FO dynamic models and controllers were introduced [3, 4, 5].
The apparent benefit of FC in the field of modelling has been justified from an industrial point of view. However, the adoption of FO-PID controllers in the industry is currently low, even though FO-PID controllers offer clear advantages in comparison with IO-PID controllers. It has been more difficult to convey the advantages of FC on the controller side because of implementation issues [6].
To fill the gap between theoretical FO-PID controllers and their practical implementation in a control hardware device, this paper proposes an architecture that facilitates their real implementation in a real-time target.
In order to test the performance of the proposed hardware architecture, several FO-PID controllers have been implemented in different control technologies and have been applied to a temperature experimental prototype that has recently been designed and developed at the University of Deusto [7].

2. Results and Discussion

Currently, industrial processes are mainly controlled using various control technologies, the most widely used being computer, microprocessor-based, or FPGA-based hardware devices [8].

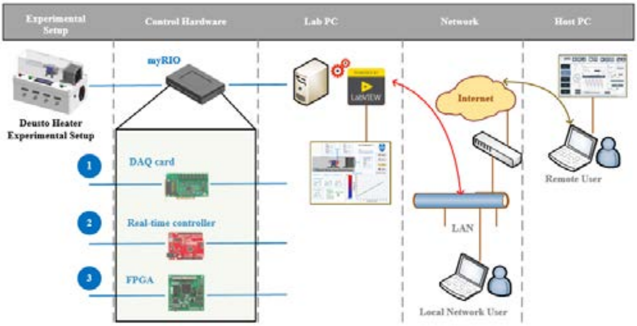

Fig. 1. Scheme of the proposed hardware architecture used to implement control algorithms in the prototype

These technologies are usually included in some Programmable Automation Controllers (PAC).
In this paper, a National Instruments® (NI) *myRIO-1900* equipment is used as a control hardware device, although any other microprocessor or control hardware could be easily incorporated.
Figure 1 shows the configuration of the control hardware architecture used for controlling temperature in the temperature prototype. The flexibility offered by this control hardware and the configuration of its control architecture allows the following control modes or control technologies:

1. Computer control, using LabVIEW programming language on the Lab PC. In this control mode, the control device is used as a data acquisition (DAQ) card.
2. Control by the NI myRIO real-time controller, where the control algorithm is implemented using LabVIEW RT and the access to input and output (I/O) ports is done through the FPGA interface. The user can interact with the control system from the Local or Host PC.
3. Control by FPGA, where the control algorithms are implemented and LabVIEW FPGA is used for accessing the I/O ports through the FPGA interface. The real-time controller manages the communication between the FPGA and the Local or Host PC.

This paper includes details about the practical implementation of FO-PID controllers with each one of the considered control technologies. In this way, the theoretical methods and developments can be validated experimentally.

3. Concluding Remarks

In this paper, a proposal of control hardware architecture for the implementation of FO-controllers is presented and applied to a laboratory setup in order to validate its performance.
The main advantage that this architecture presents from a control point of view is the flexibility in the control technologies offered to the final user that can be used. Another advantage from the implementation of control algorithms point of view of is that, regardless of the control technology used, the programming language is always the same: LabVIEW.
The way to implement FO-PID algorithms on different real-time targets is described in detail.
It is the opinion of the authors that this type of control hardware prepares engineers in the use of control technologies and low-cost FO controller-embedded system realization that will encourage industrial use of FO controllers.

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