Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Reduced Complexity Interpolative Control System for a Geothermal Heat Exchanger

Sanda Dale, Gianina Gabor and Alexandru Bara

Universiry of Oradea , 1 Universitatii Street, 410087 Oradea, Romania

sdale@uoradea.ro, gianina@rdsor.ro, albara@uoradea.ro

Keywords: interpolation, interpolative controllers, single-input controllers, geothermal heat exchanger.

ABSTRACT

The advantages of using interpolative blocks in control structures are, mainly, based on simplifying the solutions (easier implementation and reduced calculus time) and the possibility to ensure for the control systems, in a relative easy way, some robustness properties. In the same time, the controllers based on interpolation table, can be developed in much more situations than those based on linguistic rules.

This kind of controllers can be conceived starting from solutions generated in different ways, solutions that, finally, can be improved. In this context, the goal of the paper is to underline the possibilities to replace complicated controllers (conventional or fuzzy) with interpolative simple ones and to illustrate this through a case-study: the heat exchanger from the geothermal power plant deserving the University of Oradea.

1. INTRODUCTION

For simple plants of second order, fuzzy conventional regulators RG-2F with two inputs: error and change of error are sufficient for control, with satisfying performances. The idea of such a controller is based on the conventional PD and PI-type controllers. In the error-change of error plane, the command is zero along the switching line. On the sides of the switching line the values of the command are non-zero with different signs. In fuzzy approach these assumptions are also valid and the concrete values for the two inputs and the command are replaced by fuzzified information.

For complex systems all state variables are needed as state variables in order to implement fuzzy-type state-compensators. In this case the switching line is replaced by a switching hyper-plane. A complete action needs to use an all state combination as inputs for the fuzzy block. It's obvious that this approach presumes a huge number of rules and higher conceptual efforts. Due to the high complexity simpler and easier solutions were investigated, based on fuzzy-type RG-2F controllers.

In order to solve the above mentioned complex problems, some authors performed researches on using fuzzy blocks with synthetic inputs. In (Choi, 2000) single-input fuzzy controllers were developed, based on some observations related to the similarities between fuzzy and sliding-mode control. Hence, the authors suggest a new variable called the *signed distance* (*sd*), which is the distance from an actual state from the input space to the main diagonal line (or hyper-plane). This distance is positive or negative according to the position of the actual state related to the switching line/hyper plane. The derived signed distance is then used as the sole fuzzy input variable of a simple fuzzy controller.

The advantages of the single-input fuzzy developed in (Choi, 2000) are related to its reduced complexity: the control rule table is constructed on a 1-dimensional space and the number of rules is greatly decreased and also the computational complexity.

As alternative solution to the *RG_1F*, an interpolative controller *RG-1I* is also offered. Generally, the interpolative-type controllers implement the control algorithms through support points defined in interpolative blocks, which are used either alone (Drechsel, 1996) or integrated in dynamic structures (Dragomir, 2001). Hence, the second part of the paper underlines some theoretical aspects concerning the methodology used to obtain interpolative-type controllers based on synthetic-input.

The paper is organized as follows. In section 2 are presented some theoretical aspects concerning the methodology used in the paper to obtain simple single-input controllers. Experimental results obtained through simulation on a geothermal heat exchanger are presented in section 3. A few remarks conclude the presentation.

2. THEORETICAL ASPECTS

The design methodology for obtaining interpolative-type controllers based on synthetic input is fully presented in (Dale, 2006) and (Dale, 2009) and is not an issue for the present paper. A schematic procedure will be presented only with the aim to make the presentation intelligible.

Step1. In this paper, as start point for the design is considered the simple fuzzy structure with a fuzzy controller with synthetic input (RG-1F) represented in Fig.1, based on some relations between the control signal *sd* (the signed distance to the switching line in the state plane of calculus block), and e and $\dot{e}$, initially developed in (Dale, 2005). The equation considered for the signed-distance calculus is given by the expression (1).

$$sd = \frac{\dot{e} + \lambda \cdot e}{\sqrt{1+\lambda^2}} \tag{1}$$

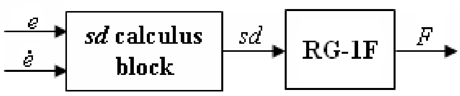

Figure 1. Signed distance *sd* calculus and the associated *RG_1F* controller.

Step2. In order to obtain an even simpler control structure, the *RG_1F* is replaced with a single input interpolative-type controller (RG-1I) like in Fig.2. The purpose is to achieve an interpolative single-input controller with, at least, the same behaviour of the control system.

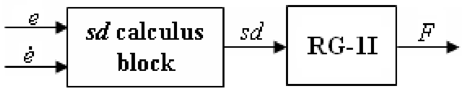

Figure 2. Signed distance *sd* calculus and the associated *RG_1I* controller.

The development run as follows: based on the single-input fuzzy controller a set of significant support points are extracted from the input-output control dependence of the RG_1F and as a result an almost identical interpolative reproduction of the fuzzy characteristic will be obtained. Such interpolative blocks can be implemented as “look-up tables” in application tools as MATLAB-SIMULINK or through other dedicated programs. Finally, a simple single-input interpolative controller RG-1I is obtained, with performances at least equal to those of the initial structure, but with less calculus time and with simpler implementation possibilities.

3. STUDY CASE

In the following it’s presented the synthesis of a simple single-input interpolative controller for controlling first agent flow in a heat exchanger with slots. The start point is the fuzzy control structure presented in [1]. In [2] are also presented the aspects related to the heat exchanger in the geothermal plant representing the process in the study case. In [3] and [10] the fuzzy controllers were replaced with interpolative ones. The aim of the present paper is to replace even these ones with simpler interpolative controllers with signed distance as sole input.

Control structure for first agent flow is a cascade control structure one. It consists in two control loops: external loop for controlling fist agent flow q_p and internal loop for state controlling the position h of the control cock, using as feedback the states h-position and r_h – speed. It can be observed that inner loop is dedicated to control the actuator (i.e. the control cock) and only the external loop acts at the first thermal agent level.

Fuzzy position controller RF-h and fuzzy flow controller RF-q are based on symmetric rules table [3], [10]. This table corresponds to a sliding-mode control strategy that provides the control values in dependence to current point position from the switching-line.

Interpolator cascade controller design is done in two steps that correspond to synthesis each interpolator block that replace in [1] the fuzzy blocks and in [10] the interpolative blocks used to control h and q respectively.

First step is dedicated to design the single-input position interpolator controller, through the procedure described in section 2. The control surface is given by a table and the implementation was realised by a look-up table 2D block. The results obtained through simulation are given in figure 3, comparatively with the results of the fuzzy control scheme.

It can be observed an evident improvement of system performances due to interpolative control actions. From the settling time point of view, is also evident that simple interpolative control is superior to fuzzy control, first (*debitint*) obtaining an 8 seconds settling time and the second (*debitfuz*) 12 seconds.

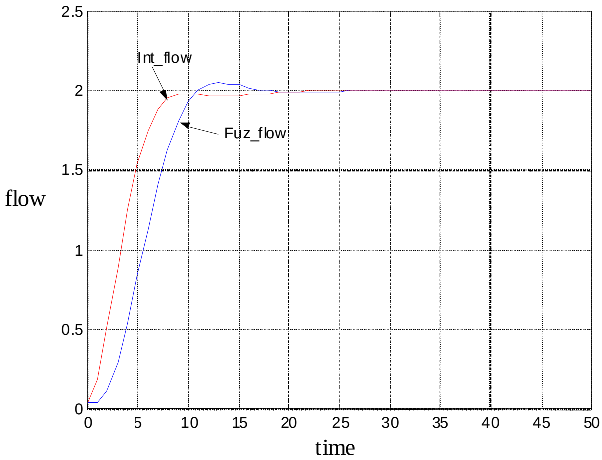

Figure 3. Step response over first modifications

At a first look, second step’s objective is to design the interpolative flow controller. Practically, by iterations, starting from a preliminary flow controller configuration, the interpolative position controller is reconfigured too. Finally it was obtained for the flow controller the dependence described by the Table 2, and for the position controller the dependence described by Table 3. It can be observed that some modifications were performed in e and r_h domains and their granulation.

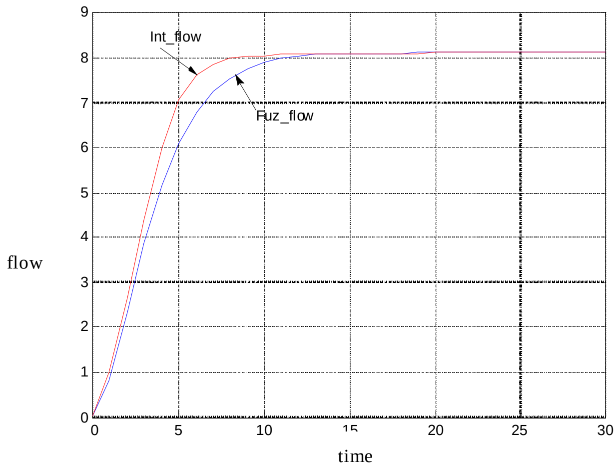

Figure 4. Step response over last modifications

From the reference signal’s point of view the performances (overshoot and settling time) of the system with interpolative controller are superior to the fuzzy system ones.

The behaviour of the two systems for first agent flow control: fuzzy control system and interpolative control systems respectively, in conditions of step modifications of pressure p_2, considered as disturbance, with a 0.2 bar amplitude around p_{20} = 1.5 bar working point is presented in Figure 5. This corresponds to a simulation scenario that includes also the situation from Figure 4.

It can be observed that disturbance rejection time is equal to transient time associated to reference modification. In both cases a good disturbance rejection exists but the fuzzy system has a less rapid reaction.

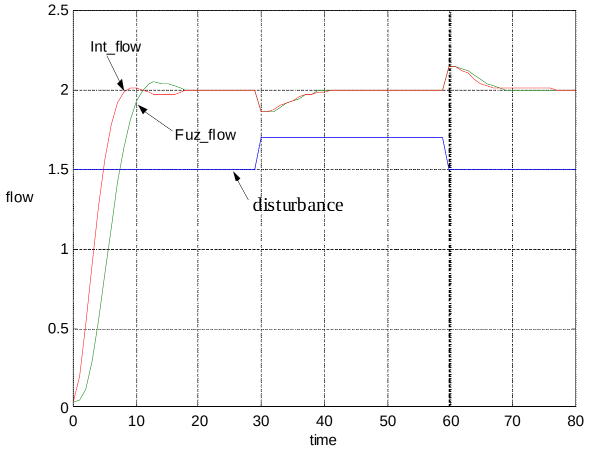

Figure 5. Responses of the two systems at pressure disturbances.

4. CONCLUSIONS

Real-world applications are challenging and complex. Control system's design may become, from this reason, hard to follow from one point further. Transparency and simplicity are important features also, for the design procedure. In this context, interpolative controllers can be present interest, from the points of view specified above and proved in the paper.

The paper explains and exemplifies how the controllers with interpolative blocks can replace fuzzy controllers in control structures. This fact is possible because fuzzy controllers belong to the interpolative-type controller category, meaning controllers which implements interpolative-type reasoning. The mentioned replacement is not only a formal operation; it is also associated with further corrections that confer to the structures with interpolative controllers enough flexibility to obtain better performances. The possibility of performances improvement is the main argument that justifies the demarche made in this chapter. Another argument is the reduced calculus time, suited for the real-time implementation - it's about "look-up table" type solutions.

In order to illustrate the working procedure, a case study - a heat exchanger from a geothermal power plant - is discussed and the experimental results encourage further studies concerning interpolative controller's introduction in control structures.

REFERENCES

[1] Bara, Al., – "Contribuții la sinteza şi implementarea sistemelor fuzzy cu aplicații la conducerea proceselor termice", teza de doctorat, Cluj-Napoca, 2000.

[2] Gabor, G., - „Contribuții la studiul disponibilității sistemelor de reglare cu aplicații la sistemul de conducere al unei centrale electrice geotermale", teza de doctorat, Timişoara, 2005.

[3] Dragomir, T.L., Dale, S., Bălaş, M.M. – "Some aspects regarding interpolative structures", Proceedings of IWICS'01, Bucureşti, pp. 6-19, 2001.

[4] Drechsel, D. – „Regelbasierte Interpolation und fuzzy control", Vieweg, 1996.

[5] Palm, R. - "On the compatibility of fuzzy control and conventional control techniques", from "Fuzzy logic – Implementation and Applications", edited by M.J. Patira and D.M. Mlynek, Wiley-Teubner, pp. 63-105.

[6] Dale, S., - „Contribuții la studiul sistemelor de reglare cu regulatoare de tip interpolativ", Editura Politehnica, Timişoara, 2006.

[7] Zadeh, L.A., – „Interpolative reasoning as a common basis for inference in fuzzy logic, neural network theory and the calculus of fuzzy If/Then rules", Opening Talk, 2nd International conference on fuzzy logic and neural networks, Iizuka, pp. XIII-XIV, 1992.

[8] Kóczy, L.T. and Hirota, K. – „Approximate reasoning by linear rule interpolation and general approximation", Internat. J. Approx. Reason. 1993/9, pp. 197-225, 1993.

[9] Dubois, D., Prade, H. and Grabisch, M. – „Gradual rules and the aproximation of control laws", John Wiley & Sons, pp.147-183, 1995.

[10] Dale, S., Bara, Al., Gabor, G., - "Interpolative Control Structure Design for a Heat Exchanger in a Geothermal Power Plant", Proceedings of EMES'07 in Journal of Computer Science and Control Systems, Oradea, 2008, pp. 131-134.