FUZZY CONTROLLERS FOR INDUSTRIAL PROCESSES

G. Conte - L. Silvestri
Dipartimento di Elettronica e Automatica
Università di Ancona
via Brecce Bianche
60131 Ancona - ITALY
fax +39-71-898246
email GCONTE@ANVAX2.CINECA.IT

KEYWORDS Fuzzy systems; PID controllers; Control of industrial processes

ABSTRACT

Controllers based on fuzzy logic have received attention by many authors in the last years and several applications have been envisaged, planned or implemented (see e.g. the collection of papers in [1]). The basic property of simple Fuzzy Logic Controllers, or FLC, that motivates this interest is their capability of providing relatively good performances using only a rough information on the plant to be controlled and on its way of reacting to control actions. Such information is in general available, coming from previous experience, or can easily be acquired. However, in the control of industrial processes that typically present delays, like thermal processes, simple FLC have proved to be ineffective or at least less efficient than traditional PID controllers (see e.g. [2], [3]).

The aim of this paper is to propose a control structure that conjugates the positive features of both Fuzzy Logic Controllers and PID Controllers and to investigate its feasibility and its performances when applied to SISO plants whose behaviour can be approximately described by linear first order processes with delay. Similar approaches have recently been proposed in [4], [5], [6]. In particular, we are interested in analysing the robustness properties of this control scheme with respect to large parameter variations that simulate failures of sensors and/or actuators in the plant.

The control structure we consider consists basically of two blocks, one is a classic PID controller, while the other is a sort of supervisor whose action is governed by a set of fuzzy rules and fuzzy logic. The PID controller actually performs the regulation task in the classical way, while the fuzzy supervisor takes care of tuning the parameters of the PID controller according to some prespecified index of performance. One advantage of this structure is the fact

that, after a choice of the PID parameters has been made and as long as no structural changes in the plant arise, the control action is independent from the behaviour of the fuzzy supervisor, that may be disconnected. From this point of view the properties of the control scheme we propose are those of a classical PID controller and can therefore be analysed and described with well-known tools.

We assume that suitable values for the parameters of the PID controller are preliminarily chosen in some way, like for instance by using Ziegler-Nichols rules, and that information on the regulation error and its derivative are fed to the fuzzy supervisor. The supervisor adjust the parameter of the PID controller in order to reduce the absolute value of the regulation error in the transient behaviour. More precisely, the output of the supervisor expresses a positive or negative percentage variation of possibly all parameters of the PID controller.

There are two different strategies for implementing the parameter variations imposed by the supervisor, namely this can be done on-line, that is before a steady-state condition is reached, or off-line, using a recursive procedure that analyses the transient behaviour of the regulated plant after each variation and then produces a further adjustment. In the first case, the fuzzy supervisor is active as long as the controller is, although its action is null after the steady-state is reached. In case sensors and/or actuators failures change the structure of the plant and cause the regulation error to move from zero, the supervisor reacts tuning the parameters of the PID controller in order to reduce the regulation error. In the second case, after the recursive procedure is completed and the parameters of the PID controller have been obtained, the action of the supervisor is turned off and in case of intervening changes in the plant the whole procedure has to be started again. According to the chosen strategy, one can therefore develop the proposed control structure into an adaptive or auto-tuning controller or into a procedure for optimizing the choice of the parameter values in PID controllers.

Two basic interlaced problems need to be addressed in order to verify the practical feasibility of the scheme described above. Namely, one has to specify, first in linguistic terms, the action to be taken on the parameter of the PID controller in order to reduce the regulation error on the basis of the available information, and, then, one has to fix a reasonable number of membership functions for every input and output variable of the fuzzy supervisor in order to make its action effective while limiting its complexity.

In the paper, an answer to the above problems is provided and its validity is discussed on the basis of simulation results. It is shown, first of all, that an efficient fuzzy supervisor may be designed using a very small number of membership functions, in many cases lesser or equal to seven, for each input and output variable. In the case of off-line tuning, the action of the supervisor consists in modifying, or tuning, all the parameters of the PID controller. The simulations show that the variations imposed by the fuzzy supervisor produce a PID controller capable of regulating the plant without causing overshoots in the transient behaviour. In case of large parameter variations in the plant, this feature may be lost, but the regulation task is still achieved. In particular, the PID controller found at the end of the recursive procedure is shown to be more robust with respect to parameter variation in the plant than PID controllers constructed by Ziegler-Nichols rules. Modifying the control scheme by adding an identification block, it is possible to implement the recursive procedure using a model of the plant, without need of exploring the transient behaviour of the actual plant after each tuning action. The technique used in the identification is a simple least square algorithm, coupled with a recursive procedure for determining the delay. By letting the PID controller act separately both on the plant and on the model, differences in the behaviour of the regulated plant and of the regulated model can be monitored and used to update the model itself by the identification procedure. The action of the supervisor has for moment been implemented only with respect to the gain parameter of the PID controller, but extensions to all the parameters are possible. The resulting transient behaviour of the regulated plant presents few oscillations of very limited amplitude. The controller reacts efficiently to sudden changes in the parameters of the plant, representing sensors and/or actuators failures, that occur after the steady-state condition is reached.

In conclusion, the results of the paper show the feasibility of the proposed Fuzzy-PID control scheme and the fact that it may represent a valid enhancement of classical PID controllers in application concerning industrial processes. Further developments of such controller will concern a more accurate specification of the membership functions and of the tuning action in order to increase its efficacy.

<u>REFERENCES</u>

[1] Proceedings of the IEEE Int. Conf. on Fuzzy Systems, 1992

[2] P. Grossi - R. Scattolini, "PID, predictive and fuzzy temperature control of nuclear magnetic resonance spectroscopy experiments", Int. J. of A.I. and Signal Processing, 5, 1991

[3] P.J. King - E.H. Mamdami, "The application of fuzzy control systems to industrial processes", Automatica, 13, 1977

[4] S. Chand, "On-line, self monitoring tuner for proportional integral derivative controllers", Proc. 30th IEEE Confernce on Decision and Control, 1991

[5] Y. Dote, "Stability of variable structured PI controller by fuzzy logic for servo systems", Proc. 30th IEEE Confernce on Decision and Control, 1991

[6] H.C. Tseng - V. Hwang - S.L. Lui, "Fuzzy servocontroller : the hierarchical approach", Proc. of the IEEE Int. Conf. on Fuzzy Systems, 1992