Chapter 14
Perspectives of Multivariable Fuzzy Control

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ABSTRACT

In this work, the situation and trends in the application of fuzzy logic control to multivariable systems are analyzed. The basic steps in designing a control system are considered. The discussion is carried out first on heuristic and reasoning approaches and, later, on function-approximation fuzzy paradigms. In both cases, apart from general considerations, some specific issues arising when considering multi-variable setups are considered.

INTRODUCTION

The situation and trends in the application of fuzzy logic to control multi-input/multi-output (MIMO) systems are analyzed. The basic steps in designing a control system are considered. Fuzzy control applications are either knowledge-based or model-based.

In model-based approaches, the first step is process modeling: Usually, interpolation and universal approximation are the two main features to be used in fuzzy MIMO systems in order to obtain a fuzzy function approximator which represents the controlled plant to a desired accuracy. For instance, the well known Takagi-Sugeno (T-S) model of the plant can be obtained. This leads to an integrated model which incorporates one "local behavior" in each fuzzy rule.

Another alternative is following a reasoning approach. In this case, a MIMO plant is treated as a whole, with as many variables as required, leading to a complex set of rules and knowledge. In this case, also an integral model of the plant is obtained.

The structure of the plant can be captured if the modeling approach deals with single input-output relationships and interactions among individual variables. In this case, a particular model can be

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attached to any single relationship, being fuzzy or not. In many cases, if a suitable structural decomposition is found for a complex plant, control becomes much easier both in fuzzy and conventional approaches.

To design the control two main approaches can be considered:

(a) The mimicking approach, trying to implement the control as explained by the experts. In this case, the MIMO structure implies a complex reasoning process with multiple antecedents and, probably, disconnected output requirements. In the same direction, the fuzzy approximation of standard MIMO control laws can be considered;
(b) Alternatively, a model based control design can be considered. For integrated models, like the T-S or global models, some recent (but now standard) control design techniques can be used: Lyapunov, LMIs,...

Another alternative is the combination of classical control laws with fuzzy interpolation and refinement. This can be used for MIMO plants with multiple operational modes as well as those with well defined single-loop controls. Fuzzy techniques allow the smooth interpolation in the transfer between operational modes and to cope with uncertain interactions, leaving the "hard" control to standard controllers. Obviously, these controllers can be also approximated by fuzzy controllers if a unique fuzzy control environment is foreseen.

In the rest of the chapter, the available techniques are reviewed, keeping in mind the specific features of MIMO systems.

The chapter structure can be outlined as follows: next section provides some background, definitions and characteristics of intelligent and, particularly, fuzzy approaches to process control. Also, issues arising in an integral plant-wide control project and where fuzzy systems may be helpful are discussed. The main focus of the chapter is split into the four next sections. First, the basic ideas behind reasoning approaches to fuzzy control (direct model-free controllers and fuzzy expert systems) are reported and a case study of a heuristic approach to control a reduction furnace is outlined. Next, an account of the function-approximation approach to fuzzy modeling and control and some universal approximation ideas are discussed. Then, the popular Takagi-Sugeno approach to model nonlinear systems, including the recently proposed fuzzy polynomial systems, is presented. Last, control design techniques for this class of systems are briefly outlined, pointing out controversies and problems. All these problems and advantages, as well as future research directions are summarized in the next section. Finally, some concluding remarks close the chapter.

BACKGROUND

Given a plant and a general knowledge about its operation, and some goals and constraints, a control problem can be defined, in the more general setting, as how to design and tune the control subsystem to be connected to the plant in such a way that the whole system achieves the goals without violating the constraints. Within this general framework, a control problem can be formulated as the regulation or tracking of some signals, the monitoring and supervision of the controlled plant operation, the optimization of some criteria, to guarantee the operation under faulty conditions or with many other different objectives.

In control research, the statement of the control problem is frequently limited to a particular issue, assuming the perfect operation of the rest of activities. For instance, to compute an optimal control, abnormal disturbances or failures, the start-up, as well as the shutting down of the plant are not considered. Also, the goals and constraints are assumed to be well defined. Under those not-too-realistic settings, specific techniques have been