A CLASSICAL CONTROLLER: A SPECIAL CASE OF THE FUZZY LOGIC CONTROLLER

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ABSTRACT

The objective of this work is to demonstrate that a classical controller is equivalent to a special case of the Fuzzy Logic Controller (FLC). The FLC is basically a piecewise linear controller. Analysis of a mathematical equation for an FLC shows that the resultant equation is a linear combination of the inputs over different ranges of operations. If the linear combination is the same over all ranges of operation, then the FLC is equivalent to the classic controller. A control surface analysis gives a clear visual interpretation of the results. Simulations of a control system produce the same results for the FLC and the classic controller.

1 INTRODUCTION

Fuzzy logic controllers (FLCs) demonstrate excellent performance in numerous applications such as industrial processes [10] and flexible arm control [8]. Mamdami introduced this control technology that Zadeh pioneered with his work in fuzzy sets [11]. Unlike "two valued" logic, fuzzy set theory allows the degree of truth for a variable to exist somewhere in the range of [0,1]. For example, if pressure is a linguistic variable that describes an input, then the terms low, medium, high and dangerously high describe the fuzzy sets for the pressure variable. If the universe of discourse for pressure is [0, 100], then low could be defined as "close to 10", "medium" could be "around 40", and so on. For control applications, linguistic variables describe the inputs of the dynamic plant and the rules define the relationships between the inputs and outputs. Thus, precise knowledge of a plant’s transfer
function is not necessary for design and implementation of the FLC. The thrust of earlier efforts involved replacing humans in the control loop by describing the operations' actions in terms of linguistic rules.

The classical controller is mathematical based and requires knowledge of the transfer function of the plant for its design. A proportional (P) controller uses a fixed gain to scale the error to produce an output. A proportional-derivative (PD) controller has an additional gain that scales the change in error input. The classical controller is a linear controller with a fixed operating point. However, the output of the FLC is dependent on the current state of its input(s). Therefore, the output of the FLC is not necessarily a constant linear combination of its input(s). Recent research into fuzzy control has applied classical techniques to stability analysis [5] and design [7, 12].

The goal of this chapter is to present a derivation of an output equation of a proportional FLC (PFLC) and a proportional-derivative FLC (PDFLC). Analysis of an FLC output equation developed by Sabharwal [10] shows that the PDFLC is a piecewise linear controller with many similarities to the classical proportional-derivative (PD) controller [1,2,5]. This chapter verifies this hypothesis and further shows that the classical controller is a special case of the FLC.

2 FLC ARCHITECTURE AND TERMINOLOGY

Figure 1 shows the components of a feedback control system that has an FLC in place of a classical controller. An FLC can be divided into three components; the fuzzification process, inference, and the defuzzification process. The fuzzification process interprets the inputs as linguistic values. Inference uses a knowledge base of rules to determine the output sets for the input linguistic values. Finally, the defuzzification process uses the output of the inference process to derive a single “crisp” output value.

Fuzzification involves dividing each input variables' universe of discourse into ranges called fuzzy sets. A function applied across each range determines the membership of the variable's current value in the fuzzy sets. The value at which the membership is maximum is called the peak value. Width of a fuzzy set is the distance from the peak value to the point where the membership is zero.