PARAMETER TUNING FOR A FUZZY LOGIC CONTROLLER

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Abstract .Modern control theory has been successfully applied in areas where systems are well defined, but it has failed to cope with systems that involve lots of uncertainty or vagueness in their nature. Fuzzy logic controllers offer a solution for problems of that type. Tuning the parameters of a fuzzy logic controller (FLC) is an important issue that is a prerequisite for any FLC application. A method for parameter selection is illustrated with application to second order linear and non-linear cases.

Keywords: Automatic control, fuzzy systems, fuzzy control, linear system, non-linear control systems

1. INTRODUCTION

Great attention has been devoted during the past decade to the application of fuzzy logic controllers in control systems. This arises from the need for a controller that can handle system imprecision, system ill-definition and uncertainty. Researchers have found FLC techniques to be a good alternative to current control techniques using highly complicated mathematical models .

An algorithm to tune the fuzzy logic controller off-line based on performance indices of the controlled system is described in this paper. The proposed technique has been tested in the design of FLC for second order linear and non-linear systems. Illustrative results are given in the paper.

2.BASIC FLC CONFIGURATION

The FLC is a knowledge based controller that utilizes the principles of fuzzy set theory in its data representation and its logic.(Zadeh,1965). The basic configuration of the FLC can simply be represented in four parts as shown in Fig.1 .

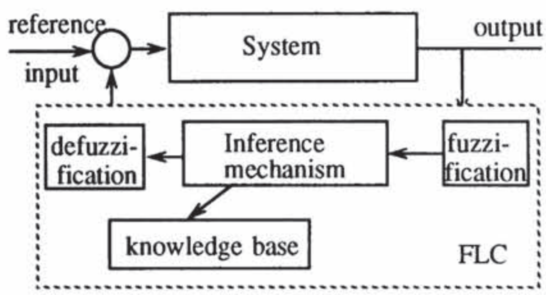

Fig. 1 The main building blocks of an FLC

The fuzzification and the defuzzification modules represent the fuzzy I/O interface responsible for converting the crisp values to fuzzy values and vice versa. The knowledge base representation provides the definitions of the fuzzy membership functions and the necessary rules that specify the control goals . The inference mechanism uses the knowledge base to infer fuzzy control actions based on fuzzy logic. Lee (1990).

3. CONTROL SIGNAL GENERATION

The generation of the control signal is based on defuzzifing the FLC decision. This decision is mainly dependent on the definition of the membership function and the rule base.

3.1 *Definition of The Membership Functions*

Consider a system described in the general form

$$\mathbf{X} = f(\mathbf{X},\mathbf{U}) \qquad (1)$$

where X = x1, x2,... are the state variables and U are the control variables.

The deviation of output from the set point (X1) and the output derivative (X2) are considered the system control variables. Each control variable is interpreted into seven linguistic variables, NB, NM, MS, Z, PS, PM, PB. (El-Metwally *et al.*, 1992). For every controlled variable X , let the whole range of X be :

$$Xspan = Xmax - Xmin \qquad (2)$$

where Xmax, Xmin are the minimum and the maximum values of the controlled variable X .

The control signal also is bounded by the minimum and the maximum values (Umin, Umax). The control signal range is also defined as :

$$Uspan = Umax - Umin \qquad (3)$$

3.2 *Definition of The Rules*

The rule definition is subjective and it is based on the operator experience and the engineer's knowledge . Lot of work has been done on the construction of the fuzzy rules by Balkini *et al.*(1975) and Shao (1988) . For a system with two control variables and seven linguistic variables in each range, it leads to a 7x7 decision table as shown in Table 1. Every entity in this table represents a rule, e.g.

if X1 is NB and X2 is NM then U is NB

3.3. *Defuzzification*

The defuzzification process takes place after the generation of the fuzzy control action using the inference mechanism. The net controller action can be calculated by weighting the *Action* associated with the fired rules by the *DOF* of the rule. Thus if the inference mechanism fires N rules the controller output U will be :

$$U = \sum_{i=1}^{N} (Action_i)(DOF_i) \,/\, \sum_{i=1}^{N} DOF_i \qquad (4)$$

Table 1 A sample set of 7 by 7 rules

Output derivative

Error	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NM	NM	NS	Z	PS
NS	NB	NM	NS	NS	Z	PS	PM
Z	NM	NM	NS	Z	PS	PS	PM
PS	NM	NS	Z	PS	PS	PM	PB
PM	NS	Z	PS	PM	PM	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

4. TUNING ALGORITHM

The objective of the tuning algorithm is to reshape the membership functions to get the desired system response. The algorithm is based on measuring three system performance indices which are the system over shoot and the performance indices J1(Σ error^2)and J2 (Σ time*error^2)

The algorithm tries to optimize the above indices by varying three parameters i.e. the ranges of the control variables (Xspan1, Xspan2) and the control limits (Uspan).

Two rules are suggested to speed up the optimization procedure. These rules detect the trend of the iteration in certain direction and try to quit incrementing the parameter that causes the divergence. The following pseudo code shows how the suggested rules work:

```
For (all parameters )
 begin
   simulate the system ;
   calculate the performance indices ;
   For( all the optimized indices )
   begin
  if ( performance INDEX degrading by DE
       GRADING FACTOR )
          allow a chance to avoid local min;
          increment the parameters increment;
          increment the CHANCE No.
  if ( CHANCE No. > MAX CHANCES )
            skip iterating this parameter for the moment.
 End (for all indices)
End (for all parameters)
```

In the above DEGRADING FACTOR and the MAX CHANCES are chosen arbitrarily based upon the desired speed of optimization.

5. SIMULATION AND RESULTS

Two systems, one a linear second order system and the other a non-linear second order system, are used for study in this paper. The first system (system 1) is described by the transfer function

$$\frac{Y(s)}{U(s)} = \frac{\omega_n^2}{S^2 + 2\,\zeta\omega_n\,S + \omega_n^2} \tag{5}$$

The second system (system 2) is described by the differential equation

$$\frac{d^2 y}{d t^2} = \omega_n^2\, y \frac{d y}{d t} - 2\,\zeta\,\omega_n \frac{d y}{d t} + \omega_n^2\, u \tag{6}$$

Simulation results with the parameters ζ=.01 , ω_n = 8, were carried out. Fort he first system, the simulation indicates oscillatory response. The system response was highly improved by using the tunned FLC as shown in Fig. 2.

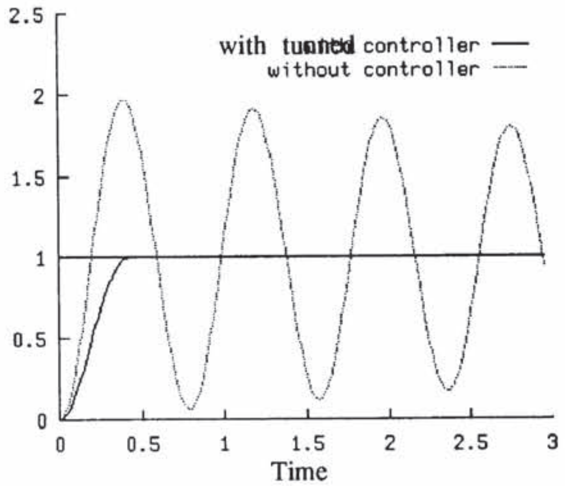

Fig. 2 system 1 response with and without FLC

For the case of the non-linear second order system. The second system results are very promising with the turned parameters. The response of the system without controller and with tunined FLC is shown in Fig.3.

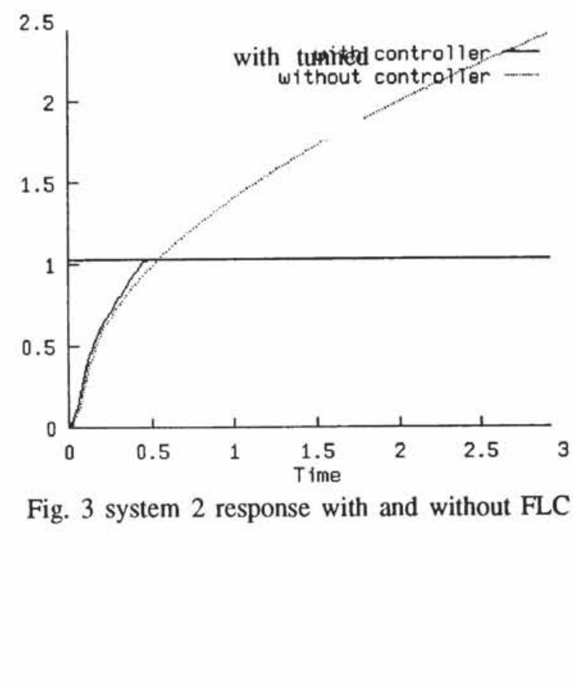

Fig. 3 system 2 response with and without FLC

6. CONCLUSIONS

A fuzzy logic controller is briefly described A suggested algorithm is described to adjust the controller parameters to give the desired performance Tuning the FLC controller parameters is successfully achieved using the suggested algorithm. Testing the tuning algorithm on two different systems shows good results.

7. REFERENCES

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