Performance of Hybrid Fuzzy and Fuzzy Self Tuning PID Controller for any Order Transfer Function

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Abstract: In any of the control application, controller design is the most important part. There are different types of controller architectures available in control literature. The controller can be conventional in nature or can be intelligent in nature. The conventional controller doesn’t possess the human intelligence; where in the intelligent controller human intelligence is embed with the help of certain soft computing algorithms. After the design of controller is performed, the performance evaluation part comes in to light. The designed controller has to give optimal control results irrespective of every situation like plant and equipment non linearity, equipment saturation. The fuzzy logic based controller meets the control objective. During the design of fuzzy based hybrid controller, the designer meets two key design challenges namely, optimization of existing fuzzy rule base and identification, estimation of new membership function or optimization of existing membership function. These issues play a vital role in controller design in real time. In real time controller hardware design there is memory and computational power constraints, so a designer needs to optimize these two design aspects. For optimization of existing mamdani based fuzzy rule base, a genetic algorithm approach is used and for identification and estimation of fuzzy membership function, a neural network based approach is used.

1. INTRODUCTION

The need for simple advanced control alternatives especially arises in the control processes area, where most of the real processes are generally complex and difficult to model [1]. The best known controllers used in the industrial processes are the conventional PID controller because of their simple structure and robust performance in wide operating conditions [2-3]. This controller deals with both time response and frequency response improvements if they are properly tuned [4-5]. But as the demands increase to control different complicated systems, performance of conventional PID controllers are tend to degrade. There is drastic change in the performance of controllers with the introduction of fuzzy logic controller (FLC) [6]. Recently, FLC have been successfully applied to a wide range of industrial processes as well as consumer products, and show certain advantages over the conventional PID controllers [7-9]. The field of Fuzzy control has been making rapid progress in recent years. Fuzzy logic control has been widely employed for nonlinear, high order & time delay system [10].

PID controllers are designed for linear systems and they provide a preferable cost/benefit ratio. However, the presences of nonlinear effects limit their performances. Fuzzy controllers are successful applied to non-linear system because of their knowledge based nonlinear structural characteristics. A FLC makes control decisions by its well-known fuzzy IF–THEN rules. FLCs can be classified into two major categories: the Mamdani type FLC that uses fuzzy numbers to make decisions [3] and a Takagi– Sugeno (TS) type FLC that generates control actions by linear functions of the input variables. In the early years, most FLCs were designed by trial and error. Since the complexity of a FLC increases exponentially when it is be used to control complex systems. Hybridization of these two controller structures comes to one’s mind immediately to exploit the beneficial sides of both categories. The two control structures are combined by a switch [3-7]. In [8] a fuzzy switching method between fuzzy controller and conventional PID controllers is used to achieve smooth control during switching. The motive to design a new hybrid fuzzy PID controller so that a further improved system response performance in both the transient and steady states can be achieved as compared to the system response obtained when either the classical PID or the fuzzy controller has been implemented.

Classical PID controller is the most popular control tool in many industrial applications because they can improve both the transient response and steady state error of the system at the same time. Moreover, it has simple architecture and conceivable physical intuition of its parameter. Traditionally, the parameters of a classical PID controller, i.e. $K_p$, $K_i$, and $K_d$, are usually fixed during operation. Consequently, such a controller is inefficient for control a system while the system is disturbed by unknown facts, or the surrounding environment of the system is changed (Panichkun & Ngaechroenkul, 2000; Pratumsuwan et al., 2010). Fuzzy control is robust to the system with variation of system dynamics and the system of model free or the system which precise information is not required. It has been successfully used in the complex ill-defined process with better performance than that of a PID controller. Another important advance of fuzzy controller is a short rise time and a small overshoot (Aliyari et al., 2007; Panichkun & Ngaechroenkul, 2000). However, PID controller is better able to control and minimize the steady state error of the system. To enhance the controller performance, hybridization of these two controller structures comes to one mind immediately to exploit the beneficial
sides of both categories, know as a hybrid of fuzzy and PID controller (Panichkun & Ngaechroenkul, 2000; Pratum suwanetal, 2010).

Nevertheless, a hybrid of fuzzy and PID does not perform well when applied to the SEHS, because when the SEHS parameters changes will require new adjustment of the PID gains. During the design of fuzzy based hybrid controller, the designer meets two key design challenges namely, optimization of existing fuzzy rule base and identification, estimation of new membership function or optimization of existing membership function. These issues play a vital role in controller design in real time. In real time controller hardware design there is memory and computational power constraints, so a designer needs to optimize these two design aspects.

2. Hybrid Fuzzy-PID Controller:

Although it is possible to design a fuzzy logic type of PID controller by a simple modification of the conventional ones, via inserting some meaningful fuzzy logic IF- THEN rules into the control system, these approaches in general complicate the overall design and do not come up with new fuzzy PID controllers that capture the essential characteristics and nature of the conventional PID controllers. Besides, they generally do not have analytic formulas to use for control specification and stability analysis. The fuzzy PD, PI, and PI+D controllers to be introduced below are natural extensions of their conventional versions, which preserve the linear structures of the PID controllers, with simple and conventional analytical formulas as the final results of the design. Thus, they can directly replace the conventional PID controllers in any operating control systems (plants, processes).

The main difference is that these fuzzy PID controllers are designed by employing fuzzy logic control principles and techniques, to obtain new controllers that possess analytical formulas very similar to the conventional digital PID controllers [8].

![Hybrid Fuzzy PID Controller](image)

Figure 2.1: Hybrid Fuzzy PID Controller

3. Hybrid Fuzzy Auto Tune PID Controller

In this section a relay based auto tuning method of PID controller is discussed. In relay based auto tuning method a relay is placed in parallel to the PID controller and both the elements are connected with a manual switch. In this section a fuzzy based auto tuning of PID controller is proposed where PID controller and hybrid fuzzy controller is placed in parallel to each other and a manual switch or selector button is used to change between PID controller and hybrid fuzzy controller. Figure 4.1 shows the Simulink representation of fuzzy based auto tuning of PID controller.[16]

![Simulink representation of fuzzy based auto tuning method of PID controller](image)

Figure 3.1 Simulink representation of fuzzy based auto tuning method of PID controller
As shown in Figure 3.1, a hybrid fuzzy controller and a PID controller is placed in parallel to each other and a manual selector switch is used to change the controller choice between PID controller and hybrid fuzzy controller. If the selector switch is set to “-1” the hybrid fuzzy controller is activated or else PID controller is activated.[17].
Figure 3.2 Flowchart of Methodology

START

PID controller

AUTO TUNER

OUTP
UT
OVER

Not possible ever

YES

NO

GO FOR
DIFFERENT
CONTROLLER

FUZZY

Define rules by hit and trial for best output

Will reduce error and best output

Define rules by hit and trial for best output

OUTPUT
OVER
SHOOT?

NO

YES

Hybrid auto tune fuzzy

Wobbling in output can't be reduced completely. Go for still better option

YES

NO

OUTPUT
OVER
SHOOT?

Final output with steady state, wobble if present the system needs to be retrain

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4. RESULTS:
The Hybrid Fuzzy auto tune PID controller is simulated for different values of Kp, Ki, and Kd.

![Figure 4.1: KP=0, KI=0.40327, KD=0](image1)

![Figure 4.2: KP=0.2957, KI=0.5420, KD=0](image2)
5. CONCLUSION:

The control scheme is separated into two parts, fuzzy controller and fuzzy self-tuning PID controller. Fuzzy controller is used to control systems when the output value of system far away from the target value. Fuzzy self-tuning PID controller is applied when the output value is near the desired value. In the terms of adjusting the PID parameters are tuned by using fuzzy tuner as to obtain the A Hybrid of Fuzzy and Fuzzy Self-Tuning PID Controller for transfer function optimum value. We demonstrate the performance of control scheme via experiments performed on the transfer function. The results from the experiments show that the proposed a hybrid of fuzzy and fuzzy self-tuning PID controller has superior performance compared to a hybrid of fuzzy and PID controller. This is because the proposed controller does not require to readjustment the parameters of PID controller although the parameters of the transfer function will change any. The advantage of the designed model over the available auto tune PID using tuning methods is that, it does not requires any mathematical modeling of the process. It uses a set of artificial rules in a decision-making table and calculates an output based on the table. While conventional PID controllers are sensitive to variations in the system parameters, fuzzy controllers do not need precise information about the system variables in order to be effective. However, PID controllers are better able to control and minimize the steady state error of the system. Hence, a hybrid system was developed to utilize the advantages of both PID controller and fuzzy controller.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Model values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of rules</td>
<td>49</td>
</tr>
<tr>
<td>Auto tuning</td>
<td>Yes</td>
</tr>
<tr>
<td>Robustness</td>
<td>More Robust</td>
</tr>
<tr>
<td>Type of Hybrid</td>
<td>Fuzzy PID + Auto Tune Fuzzy</td>
</tr>
<tr>
<td>Response time</td>
<td>Faster</td>
</tr>
<tr>
<td>Applicable to</td>
<td>Capable of operating for any order</td>
</tr>
</tbody>
</table>

Overshoot in the developed Model is Zero percent for all the cases.

REFERENCES


