Interval Type-2 Fuzzy PID Control and Simulation

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Abstract. This paper investigates interval type-2 fuzzy PID control under Gaussian and triangular primary membership functions.Three types of type-2 fuzzy PID controller simulation diagrams are given.The simulation results show the available of interval type-2 fuzzy PID control.

Introduction

The concept of a type-2 fuzzy set was introduced by Zadeh [1] in 1975 as generation of an ordinary (type-1) fuzzy set. The decade that followed, was a period of intense activity in which several authors, including Mizumoto and Tanaka [2], Yager, Dubois and Prade, and Hisdal investigated type-2 fuzzy sets and their properties. Type-2 fuzzy sets are useful for incorporating linguistic uncertainties and have found many applications[3,4].

PID control is used as the most widely control algorithm in practice. From the point of view of control system technology,fuzzy control is a universal nonlinear characterization domain controller[5-10]. In recent years,the fuzzy PID control algorithms which combine the merits of fuzzy control and PID control attract more and more attention.

Interval type-2 fuzzy inference system

In this paper, the control object is second-order inertia delay system. The time-delay is 3 seconds.Interval type-2 fuzzy PID control systems have double inputs,single output.The if-then control rules are as follows:

If $e = A_i$ *and* $\dot{e} = B_i$,then $u = C_i, i = 1,2,\cdots,7$.

Where input variables e are Gaussian interval type-2 membership functions with uncertain standard derivations, $\dot{e}$ are triangular interval type-2 membership functions,output variables u are Gaussian interval type-2 membership functions with uncertain standard derivations.In the inference procession,“singleton” fuzzifier, “min” implication, “max” aggregation, “centroid” defuzzification are used.

The membership functions of e are:

$\mu_{\tilde{NB}}(x) = \exp[-(x-m)^2/2\sigma^2]$, where $m = -20$, $\sigma \in [2.531,3.101]$;

$\mu_{\tilde{NM}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m = -13.33$, $\sigma \in [2.531,3.101]$;

$\mu_{\tilde{NS}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m = -6.67$, $\sigma \in [2.531,3.101]$;

$\mu_{\tilde{ZO}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m = 0$, $\sigma \in [2.531,3.101]$;

$\mu_{\tilde{PS}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m = 6.67$, $\sigma \in [2.531,3.101]$;

$\mu_{\tilde{PM}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m = 13.33$, $\sigma \in [2.531,3.101]$;

$\mu_{\tilde{PB}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m = 20$, $\sigma \in [2.531,3.101]$.

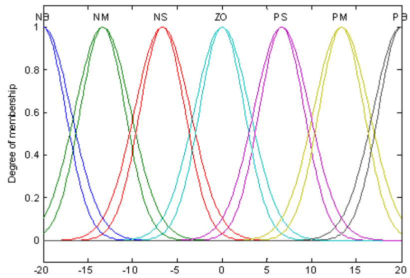

Fig.1. Membership functions of error e

In matlab,three basic points represent the lower and upper membership functions of triangular interval type-2 fuzzy sets.The membership functions of error variation $\dot{e}$ are:

NB: [-25.67, -20, -14.33], [-23.67, -20, -12.33];

NM: [-19, -13.33, -7.667], [-17, -13.33, -5.667];

NS: [-12.33, -6.667, -1], [-10.33, -6.667, -3];

ZO: [-5.667, 0, 5.667], [-3.667, 0, 3.667];

PS: [1, 6.667, 12.33], [3, 6.667, 10.33];

PM: [7.667, 13.33, 19], [5.667, 13.33, 17];

PB: [12.33, 20, 27.67], [10.33, 20, 25.67].

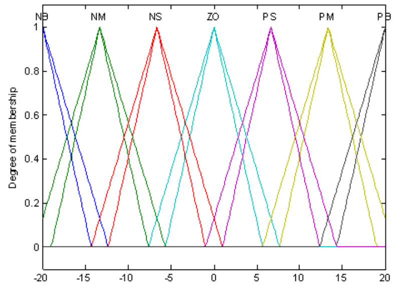

Fig.2. Membership functions of error variation $\dot{e}$

The membership functions of control variable u are:

$\mu_{\tilde{NB}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m=-20$, $\sigma \in [2.531, 3.101]$;

$\mu_{\tilde{NM}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m=-13.33$, $\sigma \in [2.531, 3.101]$;

$\mu_{\tilde{NS}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m=-6.67$, $\sigma \in [2.531, 3.101]$;

$\mu_{\tilde{ZO}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m=0$, $\sigma \in [2.531, 3.101]$;

$\mu_{\tilde{PS}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m=6.67$, $\sigma \in [2.531, 3.101]$;

$\mu_{\tilde{PM}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m=13.33$, $\sigma \in [2.531, 3.101]$;

$\mu_{\tilde{PB}}(x) = \exp[-(x-m)^2/2\sigma^2]$,where $m=20$, $\sigma \in [2.531, 3.101]$.

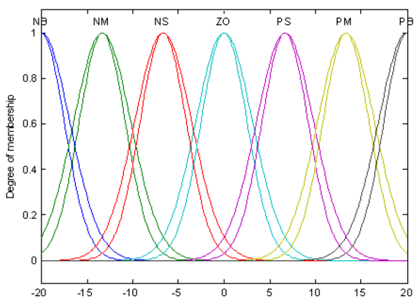

Fig.3. Membership functions of control variable u

The upper and lower membership functions construct type-1 fuzzy logic system separately.So interval type-2 fuzzy logic system is composed of two type-1 fuzzy logic systems. The fuzzy control rules table is as follows:

Tabble 1 Fuzzy control rules table

e \ $\dot{e}$	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PB	PB	PM	ZO	ZO
NM	PB	PB	PB	PB	PM	ZO	ZO
NS	PM	PM	PM	PM	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NM	NM	NM	NM
PM	ZO	ZO	NM	NB	NB	NB	NB
PB	ZO	ZO	NM	NB	NB	NB	NB

Interval type-2 fuzzy PID control

In the section, three types of type-2 fuzzy PID controller simulation diagrams are given.According to the simulation diagrams,we will develop interval type-2 fuzzy PID control algorithms responding to interval type-2 fuzzy PID simulation models in the line of type-1 fuzzy PID control algorithms.

Combination form of interval type-2 fuzzy PID control. The controller is parallel connected by a routine integral controller and two dimensional interval type-2 fuzzy controller.The simulation diagram and results are as follows:

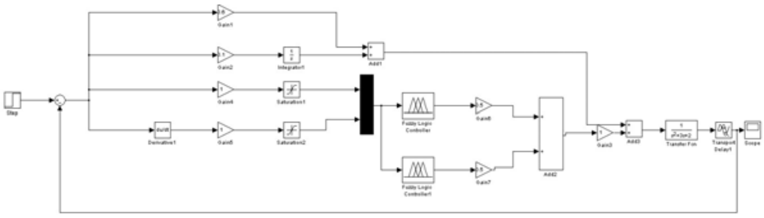

Fig.4. Combination form of interval type-2 fuzzy PID controller simulation diagram

Fig.5. Type-2 control simulation under Combination form of interval type-2 fuzzy PID controller

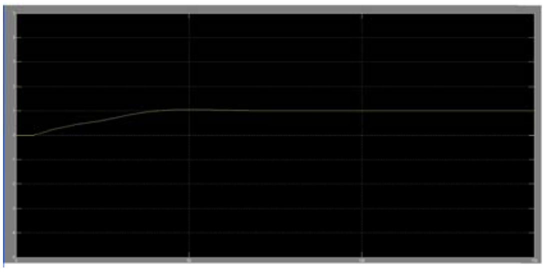

Fig.6. Type-1 control simulation

The simulation results show that the performance of interval type-2 fuzzy PID control is better than its type-1 counterpart.

Interval type-2 fuzzy PID switching control. The idea of this control mode is like this:when the derivation is high,fuzzy control is proposed;when the derivation is low,it changes to PID control.So the controller not only keeps the merit of fuzzy control but also keeps the merit of PID control. The simulation diagram and results are as follows:

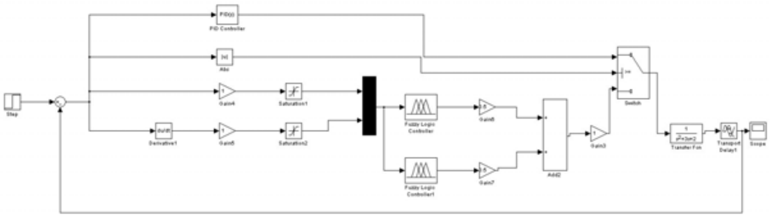

Fig.7. Interval type-2 fuzzy PID switching controller simulation diagram

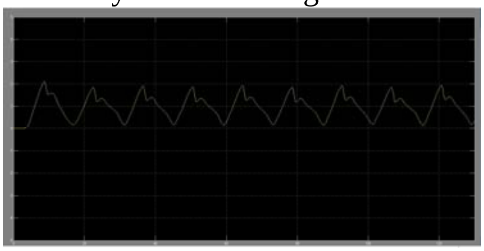

Fig.8. Type-2 control simulation under interval type-2 fuzzy PID switching controller

Fig.9. Type-1 control simulation

The simulation results show that the performance of interval type-2 fuzzy PID control and its type-1 counterpart are almost the same.

Interval type-2 fuzzy adaptive setting PID control. Fuzzy adaptive setting PID controller uses fuzzy control rules to modify PID parameters online.It chooses error e and error variation $\dot{e}$ as input,which can satisfy the requirement of e and $\dot{e}$ to the parameters of PID setting in different times. The simulation diagram and results are as follows:

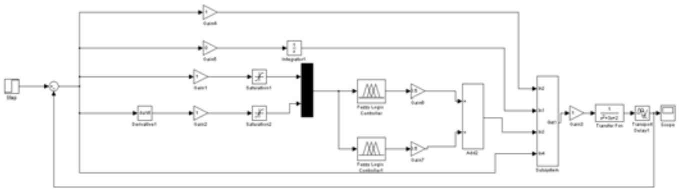

Fig.10. Interval type-2 fuzzy adaptive setting PID controller simulation diagram

Fig.11. Type-2 control simulation under interval type-2 fuzzy adaptive setting PID controller

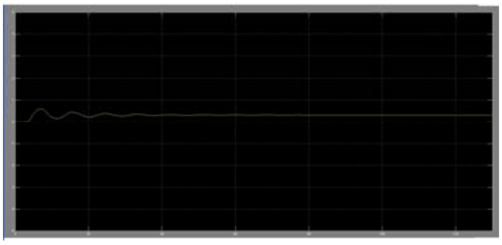

Fig.12. Type-1 control simulation

The simulation results show that the performance of interval type-2 fuzzy adaptive setting PID control is better than its type-1 counterpart.

Summary

This paper proposed three fuzzy PID control algorithms responding to interval type-2 fuzzy PID simulation models in the line of type-1 fuzzy PID control algorithms. When the fuzzy control refers to interval type-2 fuzzy sets, the lower and upper membership functions of interval type-2 fuzzy sets must be found. So the control method in the paper have some limitations.

Acknowledgment

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