조준경 안정화 장치의 적응 퍼지 논리 제어
Adaptive Fuzzy Logic Control for Sight Stabilization System

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Abstract

The rule based self organizing controller(SOC) has one of its main advantages in the fact that there is no need to have a mathematical description of the system to be controlled. In this controller, the rules are linguistics statements expressed mathematically through the concepts of fuzzy sets and correspond to the actions a human operator would take when controlling a given process. With this controller, we have performed to sight stabilization system, and we realize that it needs a scale factor tuning. The self tuning controller(STC) uses an instantaneous system fuzzy performance which can give an inspection to the scale factor. Therefore. the STC can compensate the scale factor when it is not adequately tuned. With this trial, we shows that STC can give a good transient characteristics in the nonlinearity which imposed basically in the conventional servo system.

1. Introduction

Most of the real world processes that require automatic control are nonlinear in nature. Fuzzy logic controllers (FLC) are nonlinear and so they can be designed to cope with a certain amount of process nonlinearity. However, such design is difficult, especially if the controller must cope with nonlinearity of the process. Also the rules of the FLC do not contain a temporal component, so they cannot cope with process changes over time. So there is need for adaptive FLC as well.

An FLC which is able to develop and improve the fuzzy rules and structure automatically as a result of monitoring the process performance so as to obtain a predetermined quality is called a self organization fuzzy logic controller (SOFLC or SOC) [1,2,6]. This controller can be applied to different processes such as ones in any dimension : single-input single-output or multivariable.

Even though SOC can construct a rule base, it has some problem to satisfy the system performance when the scale factor is not adequately tuned. Therefore, there is need to tune the rules and the scaling factors for good performance after the establishment of control rules. Because this labor requires time consuming efforts. a real time self tuning fuzzy logic controller (STFLC or STC) has been developed [3,4,7].

Finally. a simulation of sight stabilization system is implemented to verify the proposed method in this paper.

2. Self Organizing Fuzzy Logic Controller

The configuration of the self organizing fuzzy logic controller is shown in figure 1. The controller is composed of two parts. One is the conventional fuzzy controller and the other is the self organizing controller [1,2,5].

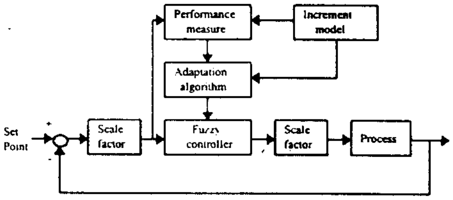


Figure 1. The self organizing fuzzy controller block diagram

The conventional fuzzy controller has a simple structure which has been tested successfully in the fuzzy literature. The controller inputs are the conventional error (e) and change of error (ce), while the control signal (u) is a controller output. The two input signals are mapped from physical values to normalized values by using the input scaling factors (GE and GCE). The output fuzzy set of the controller is defuzzified, scaled by the output scaling factors (GU) and applied to the process.

The self organizing controller employs process performance feedback. where the performance index issues a correction value to individual control actions that contributed to the present process state. The performance of the fuzzy controller can be described by the difference between the required and actual state responses. The performance index takes the form of a correction maker which issues the output corrections required from a current knowledge of e(nT) and ce(nT). The performance measure rules can be transformed into a numerical look up table using standard techniques of fuzzy calculus as in table 1 for brevity's sake.

Table 1 The numerical performance index

	NB ← Change of Error → PB						
NB	-3	-3	-2	-2	-1	-1	0
↑	-3	-2	-2	-1	-1	0	1
	-2	-2	-1	-1	0	1	1
Error	-2	-1	-1	0	1	1	2
	-1	-1	0	1	1	2	2
↓	-1	0	1	1	2	2	3
PB	0	1	1	2	2	3	3

The correction of the control action for a single input single output(SISO) process can be given as :

$$P_i(nT) = K^{-1}P_o(nT) \qquad (1)$$

where P_i is the performance index reinforcement, P_o is the required output change, and K is the process static gain. If the values of the process input and output are scaled and then normalized to their maximum values, then K becomes unity.

The rule modification is based on reconstructing the set of rules in the rule base. The basic structure of the original relation matrix is given by :

$$R'(nT) = E(nT-dT) \times CE(nT-dT) \times U(nT-dT) \qquad (2)$$

and according to the correction value issued by the performance index, P_i , this relation should be modified to:

$$R''(nT) = E(nT-dT) \times CE(nT-dT) \times V(nT-dT) \qquad (3)$$

If R(nT) is the relation matrix at the present instant and R(nT+T) is the updated one, then

$$R(nT+dT) = \{R(nT-dT) \cap \overline{R'(nT)} \cup R''(nT)\} \qquad (4)$$

To keep the rule base consistent, only rules with a new antecedent should be added to the rule base, while rules with different consequent and similar antecedent are modified.

3. Self Tuning fuzzy Controller

A self tuning fuzzy controller can be represented by the block diagram as shown in fig. 2.

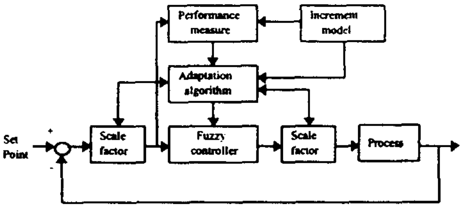


Fig. 2. Self tuning fuzzy logic controller

3.1 Scaling factors and rules

Scale factors map the input/output value to the fuzzy variable domain. The change of input scaling factors connects input values to suitable rules, and the change of output scaling factors can adjust the amplitude of the control output[3,4].

Generally, the modification of control rules changes the characteristics of the gain function. The adjustment of the scaling factors determines the tilt of gain characteristics, so we know the adjustment of scaling factors is important in tuning the controller.

3.2 The Instantaneous system performance

The instantaneous system performance is to determine the system performance at the sampling time. Fig. 3 shows the relationship of error and change of manipulated values for the general response of step input which has oscillation with exponential decay.

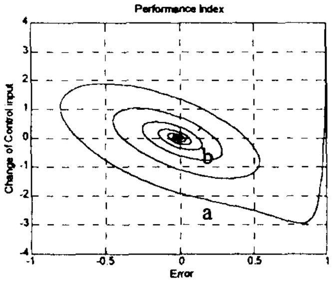


Fig. 3 State trajectory of Error and change of manipulated value

In this figure, the control reaches the set point when the value of error and change of manipulated value have reached zero point. So the value of error and change of manipulated value are used to determine the grade of instantaneous system performance for scaling factor tuning. The instantaneous system fuzzy performance((ISFP) are defined as follows:

$$ISFP_e(t) = \mu_{ISFP_e}(e(t))$$
$$ISFP_{\Delta u}(t) = \mu_{ISFP_{\Delta u}}(\Delta u(t)) \tag{5}$$

Eq. (5) means the grade of instantaneous system fuzzy performance for the error (e) and change of the manipulated value (Δu), respectively. by the ISFP rules presented in table 2. The instantaneous system performance is defined as follows:

$$ISP = \min\{ISFP_e(t), ISFP\mu_{\Delta u}(t)\} \tag{6}$$

we can find that if ISP(t) approaches 1, that is to say, the system performance at t is good grade. In this case the value of (e) and (Δu) are close to 0. Finally the scale factor is tuned in real time using equation as follows:

$$SF(t) = SF(t-1) + W_t(1 - ISP(t))\Delta SF \tag{7}$$

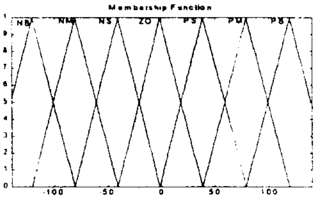
where

$$R_k = E_k \times C_k \times \Delta U_k$$

$$R = R_1 \cup R_1 \cup \cdots R_k = \bigcup_{k=1}^{n} R_k$$

$$\Delta SF = (E \times C) \circ R$$

SF(t) is the scaling factor at t, Δ SF the varying quantity of scaling factor which is the result of fuzzy reasoning and W_t is the weighting factor



Error, Change of manipulated value U

Fig. 4.a The normalized membership function for E and ΔU

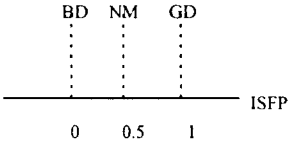


Fig. 4.b Normalized membership function for ISFP

Table 2. Instantaneous Performance Decision Table

	NB ← Change of Control Input → PB						
NB	BD	BD	MD	MD	MD	BD	BD
↑	BD	MD	MD	GD	MD	MD	BD
	MD	MD	GD	GD	GD	MD	MD
Error	MD	GD	GD	GD	GD	GD	MD
	MD	MD	GD	GD	GD	MD	MD
↓	BD	MD	MD	GD	MD	MD	BD
PB	BD	BD	MD	MD	MD	BD	BD

4. Sight Stabilization System

Sight stabilization system is used to search and track the targets in the field. The function of sight stabilization system is similar to periscope in the submarine. The artilleryman can see the target image that reflected in the mirror and track it to fire the gun. Because he sees the target image through the stabilized mirror, it requires a fast transient characteristics and good steady state error. It has the nonlinearity such as coulomb friction, power limit etc. Between these characteristics, the steady state error is very important, so it adopts a typical PID controller.

5. Simulation

The system transient responses show some differences at each set point which is shown in fig. 5. This is obtained from the experiment at the real plant. These characteristics mainly due to the nonlinearity of the system and using a fixed PID gains in the controller.

In SOC case, the rule table has null values at first and it is filled with an adequate rule from a performance decision table. The fig. 6 is the step response when the set point is 1°. In this case, we tuned the scale factor with trial and error. The fig. 7 is the normalized step responses of several set point that the scale factor is fixed with a number obtained in the set point 1°. As we can see in this result, it gives a better result than PID controller in the transient region. In the fig. 8 and fig. 9, we would like to investigate the effect of inadequate scale factor. This shows that the SOC needs a scale factor tuning irrespective of their learning ability of necessary rule.

The step response of self tuning controller with real time is shown in fig. 10~ 11. In the overshooting case, it shows some overshoot in a transient phase. It is mainly caused that the system has too fast to compensate an inappropriate scale factor. Without this fact, we can get a satisfactory transient characteristics than SOC result. With this result, we expect that the self tuning method with PD type fuzzy controller are useful with a controller which has some nonlinearity.

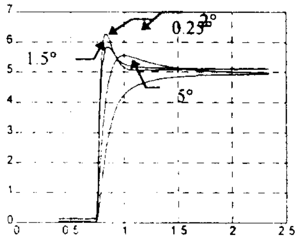


Fig. 5 The normalized system response with different setpoints.

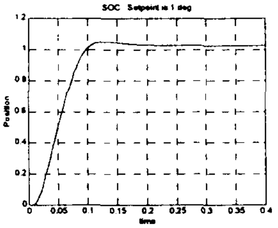


Fig. 6 The system response of SOC with tuned scale factor

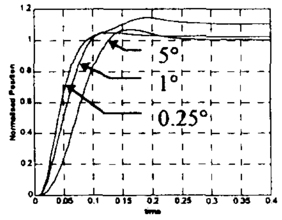


Fig. 7 The comparison of system response of SOC with fixed scale factor

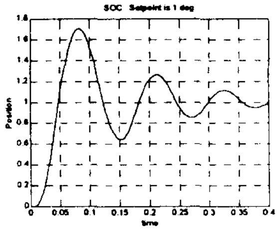


Fig. 8 The system response of SOC with large scale factor

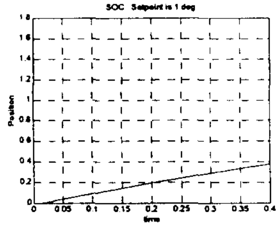


Fig. 9 The system response of SOC with small scale factor

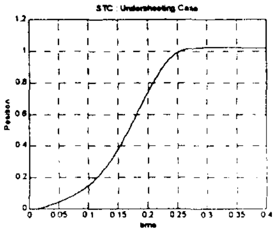


Fig. 10 The system response of STC : Set point is 1°

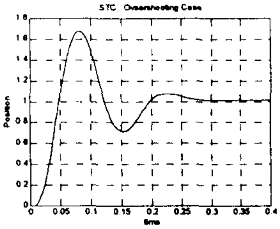


Fig. 11 The system response of STC : Set point is 1°

6. Conclusion

In this paper, we construct a self organizing fuzzy logic controller for sight stabilization system which has a nonlinear characteristics such as coulomb friction and power limitation. The SOC with tuned scale factor shows a good performance than PID controller. But, SOC has a some problem when the scale factor is not adequately adjusted. Therefore, it needs to tune the scale factor.

In order to solve the scale factor tuning with real time, we adopted a instantaneous system fuzzy performance. With this trial, we can solve the real time self tuning controller which has a mistuned scale factor, and can get a good transient characteristics.

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