Research on Dynamic Control Modeling for AFS System

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Abstract.A new dynamic control model for Adaptive Front-lighting System(AFS) is presented in this paper based on pan-Boolean theory. This logical control model for AFS system is based on control practice for AFS system and is consisted by a series of control rules. Combining with PID control arithmetic, off-line simulation with Rule and PI control arithmetic is practiced. Its simulation results show that the structure of control model is simple, and it is easier to be controlled and realized.

1. Introduction

AFS (Front-lighting System Adaptive) is a newly technology for passenger cars developed by BMW[1]. The working principle of AFS is that: when a vehicle came into the corner, controller can collect the speed and steering angle changes, to determine whether dimming the level of the headlight or not, and calculates the adjusting angle between the left or right of the headlights. Then send signal to the drivers to control the corresponding stepper motor for completing the dimming process. The automobile adaptive front lighting system includes sensor module, controller, driver, stepper motor, headlights.

The dynamic model of the AFS system explains the theory of the relationship between the driving information and the adjusting angle. But in practice, if the output result of the AFS dynamic model is directly dependent on the model to control the execution mechanism of the AFS system, this kind of controlled object with the characteristics of pure delay and large inertia has some problems, including existing some angle control error, not solving the system performance index, difficulties to unify the stability, accuracy and speed, and the object parameters are sensitive to parameters, and the system robustness is not strong[2].

2. AFS rule control model based on pan-Boolean theory

The mathematical model of AFS system can accurately express the relationship between input signals such as wheel angle signal, vehicle speed, vehicle high signal and output signal such as adjust angle of the output level, perpendicular direction. The controlled object of the system is the stepper motor. The mathematical control model of AFS control system is obtained by setting the deflection angle of the stepper motor as the controlled parameter. The mathematical model can be expressed as the two order inertial link with the pure delay. It is very difficult to establish accurate mathematical model by the way of theory analysis, which baffles improving in control capability of AFS system. There are two ways to solve this problem. One way is that by the way of such as PID control; the other is by the way of intelligence control without accurate mathematical model such as Fuzzy control to realize high precision in angle control for AFS system[3]. Above two ways are not easier to be realized. Based on pan-Boolean algebra theory, a novel dynamic control model and intelligent control way are presented in this paper.

The construct figure for AFS control system is shown as Fig.1. The control model of AFS system depends on work states such as angle error e and $\dot{e}$. It applies logic rules to decide how controller outputs based on some experience data.
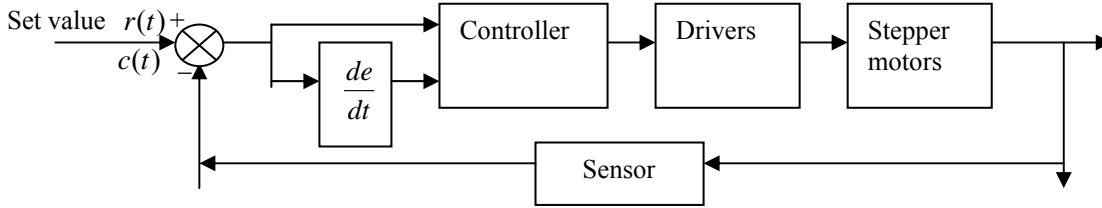
Fig.1 AFS control system

Base on ideal of pan-Boolean theory is that, let $x_1, x_2, x_3, ..., x_n$ be factors in a manual control system, and call any factors x_i that maybe appear as numbers of factors corresponding to x_i, numbers of factors may be also denoted as $n_i (i = 1, 2, ...)$. Also let $x_i^j (i = 1, 2, ...; j = 1, 2, ..., n_i)$ be symbol state called j corresponding to x_i. x_i is called state numbers of factors. Symbol state value is 1 or 0. In multimode system, each state numbers of factors only choose single state in n_i state in some certain situation, Eq.1 and Eq. 2 are required to be sufficed synchronously[4].

$$x_i^1 + x_i^2 + \cdots + x_i^n = 1 \qquad (1)$$
$$x_i^j \cdot x_i^k = 0 (1 \le j < k \le n_i) \qquad (2)$$

Logic control based on pan-Boolean algebra theory is presented in this paper based on front-light angle control of pan-Boolean algebra theory. By letting angle error and change in error of AFS system angle sensors as feedback signal, at the basic of some experiments and experience data, using logic rule of pan-Boolean algebra, ascertain control drivers output, corresponding to control system response.

Running rule is shown as table1 by symbol. Let x_1 represent angle error. Corresponding to $x_1^0, x_1^1, x_1^2, x_1^3$ and x_1^4 represent five kinds of state that angle errors are "positive large, positive small, zero, negative small, negative large". Let x_2 represent error change in angle error, corresponding to $x_2^0, x_2^1, x_2^2, x_2^3$ and x_2^4 represent five states that change in angle error are "positive large, positive small, zero, negative small, negative large". If k_i represents adjustment angle value of the stepper motors, corresponding to range of k_i is respectively: k_0 is $\{ -e_0 \le e \le e_0$ and $-\dot{e}_0 \le \dot{e} \le \dot{e}_0 \}$. k_1 is $\{ e > -e_0$ and $\dot{e} \le \dot{e}_0 \}$、k_2 is $\{ e \le e_0$ and $\dot{e} \le -\dot{e}_0 \}$、$k_3$ is $\{ e \le -e_0$ and $\dot{e} \ge -\dot{e}_0 \}$、$k_4$ is $\{ e > -e_0$ and $\dot{e} \ge \dot{e}_0 \}$. k_0, k_1, k_2, k_3, k_4 represent respectively angle adjust "remain, much plus, slightly plus, slightly minus, much minus" etc five control strategies, above-mentioned control rule are shown as table 1. Table 1 shows twenty-five kinds of control strategy, every control strategy corresponding to trend of system movement. All control rules is named as rule control model of AFS system

Table1 Pan-Boolean theory control rule symbol table

e \ $\dot{e}$		positive large x_2^0	positive small x_2^1	$\dot{e} = 0$ x_2^2	negative small x_2^3	negative large x_2^4
positive large	x_1^0	k_1	k_1	k_1	k_1	k_2
positive small	x_1^1	k_4	k_0	k_0	k_0	k_2
$e = 0$	x_1^2	k_4	k_0	k_0	k_0	k_2
negative small	x_1^3	k_4	k_0	k_0	k_0	k_2
negative large	x_1^4	k_4	k_3	k_3	k_3	k_3

Its control rules can be directly described in phase plane. Control experience shows that k_1 determines ascending time, the bigger its value is, the fewer ascend time is, k_2 can restrain positive overshoot in advance, k_3 makes response fast and force error to return fast to enactment

value. k_4 can restrain negative overshoot in advance. k_2 and k_4 can restrain disturbance effectively, make system output clamp in the range of error that enactment value allows[5].

Compared with general control ways, the rule controller has some advantages of fast response speed and smaller overshoot, etc. But the rule controller has not integral module, and input signal in process is limited and discrete, and output signal is dithered, so the controlled object exists steady state error near balance point, even little swing surge phenomenon appears. In small range near balance point, effect of PI controller is perfect. Its integral effect can eliminate remnants error finally. So the Rule with PI sectionalized multi-mode control way of AFS system is presented. When angle error is very big, Rule control is adopted; when angle error is very little, PI control is adopted. Rule-PI multi-mode subsection control colligates the advantages of Rule control and PI control. System has the advantages of fast response speed and smaller overshoot, it can also realize higher steady state positioning precision. AFS system Rule-PI subsection multi-mode control structure is shown in Fig.2.
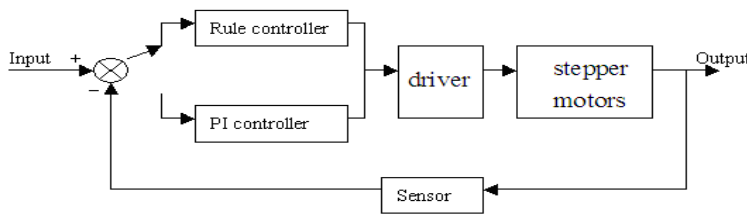

Fig.2   AFS Rule-PI multi-mode subsection control structure

In Fig.2, if $|e| > e_0$, Rule control is adopted; when $|e| < e_0$ PI control is adopted. e_0 is error gate value switch between logic rule control and PI control. Value of e_0 is determined by control precision.

3. Simulation for the AFS rule control model

The mathematical control model of AFS control system is obtained by setting the deflection angle of the stepping motor as controlled parameter. The mathematical model can be expressed as the two order inertial link with the pure delay. Generally, the motor control system is composed of two order inertia link and a pure lagging link. According to the experimental data of the system identification, the model of stepper motor can be obtained as Eq.3 [6]:

$$G(s) = \frac{ke^{-\tau s}}{s(Ts+1)} \quad （3）$$

Where k is proportional coefficient，value is 2.93；τ is pure lag time，value is 0.06，T is time constant，value is 1.77.

Simulation object is AFS control system, if control precision is fixed to 0.001, only fixing error zero region to 0.001 is needed, in Fig.3, value k indicates value of acted force in every work states, Control coefficient k is adjusted respectively. Control coefficients are adjusted respectively according to the response of object. Because capability index of system is related with quality parameter of system, the change of plus parameter of closed-Loop system can change these quality parameters. Because logic rule controller can analyze mutual effect between above-mentioned capability and index, control mode becomes simpler, and it is easier to operate neatly to optimize capability.
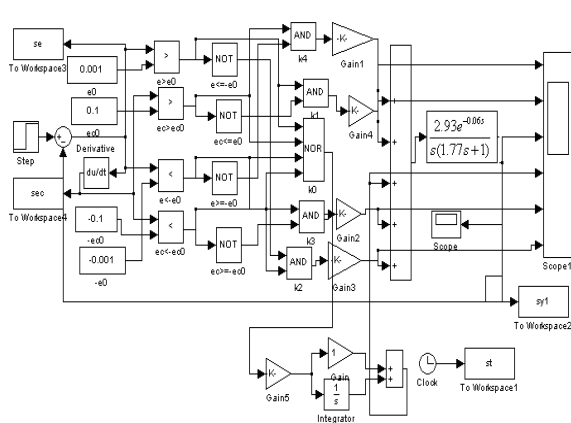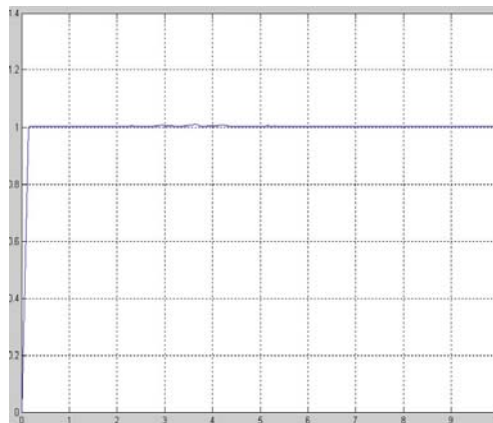
Fig.3 Simulation model of AFS

Fig.4 Step response simulation curve

When input signal is step-function signal, and its value is unit voltage, its response curve is shown as Fig.4. It shows that if we adopt Rule with PI multi-mode subsection control, overshoot almost can not be found, and ascending time is very little.

4. Conclusion

The simulation experiment indicates that this control model, based on pan-Boolean algebra theory and control experience of AFS control system, is very convenient, simple and intuitionistic. Rule with PI controller control strategy is used in AFS control system is simple. And complex mathematical operation is not needed in practice. Control effect is super than general control way.

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