DESIGN OF THE SIMPLE CONTROL ALGORITHMS ON THE BASIS OF THE FUZZY APPROACH

Víteček, Antonín - The College of Mining and Metallurgy in Ostrava

An article describes, in brief, design of control algorithms on the basis of the fuzzy approach and pays attention to some of the significant view-points which should be used as a starting position. This procedure eliminates most of troubles arising both in the course of designing and particularly during debugging and implementation designed algorithms.

1. Introduction

In spite of the enormous development of the control theory and identification methods there is still a number of processes with the static and dynamic behaviour that doesn't allow to automate their control. These processes are often successfully controlled by human operator. The fuzzy approach as a basis of the design of the control algorithms is one of the way how to automate control of these processes; here methods of the design based on the deterministic resp. stochastic approach don't bring satisfactory results.

2. Fuzzy approach

Designer of the control systems elaborates, on basis of word description of partial control interventions of the experienced operator, linguistic control algorithm in a form of a set of partial implications; all the variables are considered as the linguistic variables /1-3/. This stage is already accompanied with the big problem - with a choice of the type of control algorithm. Even very experienced operator doesn't exactly know if he operates with the absolute values or with the increments. So the choice of the inadequate type of the control algorithm can cause that the desired quality of the control performance isn't achieved; there can appear instability etc. This fact aggravates correct debugging of the designed algorithm and its utilization or even makes it impossible.

Fuzzy approach leads to the non-linear deterministic control algorithms /1,3/, which can be divided similarly like conventional algorithms into followig types:

$$\begin{aligned} &P \quad \dots \quad & u_i &= R(e_i), \\ &I \quad \dots \quad & \Delta u_i &= R(e_i), \\ &PD \quad \dots \quad & u_i &= R(e_i, \Delta e_i), \\ &PI \quad \dots \quad & \Delta u_i &= R(e_i, \Delta e_i), \end{aligned} \qquad /1/$$

where u_i resp. Δu_i is manipulated variable resp. its increment, e_i resp. Δe_i is control deviation resp. its increment, R is real function, i is index corresponding with an instant of sampling $t_i = i\ T_v$ $/i = 0,1,2,\dots/$, T_v is a sampling interval.

Change in the sampling interval T_v influences integral resp. derivative action in algorithms /1/ by the way similar to the corresponding conventional algorithms. More complex types of algorithms aren't considered, as the operator isn't able to react continuously on more than 2 variables /3/.

Choice of the suitable type of the control algorithm can be based on adaptive properties of human operator acting in a closed loop of the control system. After obtaining the necessary training the operator conforms himself to behaviour of the controlled system so that the closed loop control system is stable and along with it the open loop control system has a character of the integral element /3/. On the basis of the following table designer and operator should choose, therefore, the same type of the control algorithm:

CONTROLLED SYSTEM	TYPE OF CONTROL ALGORITHM
static	I, PI
1st order astatic	P, PD /PI/
2nd order astatic	/PD/

Algorithms in parentheses can be accompanied with problems of stability.

As for concretization of the partial implications /algorithm PI is considered/ in a form /1-3/:

$$R_j \ \ldots \text{ IF } e_i = x \text{ THEN IF } \Delta e_i = x \text{ THEN } \Delta u_i = x, \qquad /2/$$

where R_j is a partial control intervention $/j = 1,2,\ldots,N/$; N is a number of the partial control interventions; x is a linguistic value of the respective variable, a next big problem arises - choice of a number of linguistic values /e.g. PB = positive big, AZ = approximately zero etc./. A number of linguistic values can differ due to the different variables in the control system. As a rule 5-7 linguistic values are used /1-3/. It seems it is due to limitation of human memory what is in the accordance with the hypothesis of capacity of operating human memory expressed by a number 7 ± 2 /3/.

After elaborating partial implications /2/ the resultant linguistic control algorithm can be written in a form of a relation /1-3/:

$$R = R_1 \text{ ELSE } R_2 \text{ ELSE } \ldots \text{ ELSE } R_N. \qquad /3/$$

Linguistic values x can be quantified by fuzzy sets expressed by their membership functions μ_x. Choice of the membership function form for the respective linguistic values isn't critical /3/.

The fuzzy algorithm can be achieved from the linguistic algorithm by the formal transcription through min-max compositions /1-3/. For example, as to the chosen type of the control algorithm PI /3/, the fuzzy algorithm has a form of the fuzzy relation with membership function:

$$\mu_R(e_i, \Delta e_i, \Delta u_i) = \max(\mu_{R_1}, \mu_{R_2}, \ldots, \mu_{R_N}), \qquad /4/$$

where membership functions μ_{R_j} are given by the relationships:

$$\mu_{R_j}(e_i, \Delta e_i, \Delta u_i) = \min[\mu_x(e_i), \mu_x(\Delta e_i), \mu_x(\Delta u_i)], \qquad /5/$$

$$j = 1,2,\ldots,N.$$

The compositional rule of inferece is used in the conection with the determination of the membership function of the actual intervention /1-3/, e.g. we can achieve from the relationship /4/:

$$\mu(\Delta u_i) = \max_{\Delta e_i} \min\left\{\mu_x(\Delta e_i), \max_{e_i} \min\left[\mu_x(e_i), \mu_R(e_i, \Delta e_i, \Delta u_i)\right]\right\}. \quad /6/$$

As in the instant of sampling t_i control deviation e_i and its increment Δe_i have tangible numeral values e_{i0} and Δe_{i0} then:

$$\mu(\Delta u_i) = \mu_R(e_{i0}, \Delta e_{i0}, \Delta u_i). \quad /7/$$

The tangible value of the manipulated intervention Δu_{i0} is usually determined using the relationship /1-3/:

$$\Delta u_{i0} = k_R \frac{\int \Delta u_i \, \mu(\Delta u_i) d\Delta u_i}{\int \mu(\Delta u_i) d\Delta u_i}, \quad /8/$$

where k_R is suitably chosen gain coefficient. Its value is close to 1 and can be determined on the basis of the experimental verification of the designed algorithm, e.g. from the requirement on control time, maximum overshooting etc.

3. Conclusion

Design of the simple control algorithm on the basis of the fuzzy approach leads to non-linear deterministic algorithms of the types P, I, PD and PI. Choice of suitable type of the control algorithm must be based on the behaviour of the controlled system.

Thanks to the fuzzy approach it is possible to get quantitative expression of the approximate qualitative description of operator's control action. It can serve as a basis for the elaboration of more perfect control algorithm by conventional methods.

4. References

/1/ Braae M.,Rutherford D.A.:Fuzzy Relation in a Control Setting.Kybernetes,Vol.7/78,pp.185-188

/2/ King P.J.,Mamdani E.H.:The Application of Fuzzy Control Systems to Industrial Processes.Automatica,Vol.13/77, pp.235-242

/3/ Víteček A.:Fuzzy Approach to Design /in Czech/.VŠB 1982