Control System Design Conformable to Physical Actualities

Toshiyuki Kitamori

NF Corporation, Professor Emeritus, University of Tokyo

Tsunashima-higashi 6-3-20, Kohoku-ku, Yokohama-shi 223-8508, Japan

toshi.kitamori@jcom.home.ne.jp

Presented here is a unified design method which covers from linear continuous-time to sampled-data, from linear to smooth nonlinear, and from SISO to MIMO decoupling control. The method has been constructed strongly related to physical and empirical actualities. One of the physical actualities is that the controlled object is, in general, a combination of nonlinear distributed-parameter systems with highly complex boundary conditions. Therefore we can hardly build up any accurate model for analysis and design. Any modeling whatsoever is an approximation. Empirically, however, we know that a lower-order approximation is effective if the time evolution speed is not so high, and that a linear approximation is effective if the range of variation is sufficiently narrow. In the simplest application even static approximation is useful. Thus we are to work on these varieties of approximated modelings.

For control system design, we can think of an equation such as

[controlled object](connection)[compensator/controller]=[desirable control system].

In order to determine the compensator/controller, we have to rewrite the equation in some convenient expression to handle with. The expression should be convenient for the measurement of controlled object dynamic characteristics, convenient for the specification of desirable control system, and convenient to solve the compensator/controller. For the convenience of solving the compensator/controller, the expression turns out to be such that the series connection and the parallel connection of two transfer elements and the inverse of each element are easily calculable. For the convenience of object dynamic characteristics measurement, the expression turns out to be such that if observable phenomena are continuous with respect to any parameter change then the expressions are continuous with respect to the same parameter change.

Considering that the static approximation is a special case of dynamic approximation, we can derive a convenient expression for solution of compensator/controller, which turns out to be the transfer function. Furthermore the transfer function expression is assured adequate for the measurement of controlled object dynamic characteristics.

Rewriting the equation in the transfer function expression, for the most popular PID control, and solving the controller, we can see the essential information needed is not the transfer function but the denominator-expanded-form of the transfer function, which is the MacLaurin series expansion of the inverse of transfer function. The expression reserves the calculability of series and parallel connections and inverse. In addition, it has a very convenient property named as IFS (independency from successors), which allows us to truncate at any terms in the four basic operations of arithmetic, independently from the succeeding terms. From simple simulation studies we can see that the higher order terms of the transfer function or the denominator-expanded-form have little effect on the performance of control. The fact serves the validity of lower-order approximation of distributed-parameter system and we can get very simple design formulae, based on the partial model matching from the lowest to the higher terms corresponding to the number of adjustable parameters.

Although PID control scheme is the most popular in the actual field, we can obtain I-PD control scheme from basic consideration of dynamic compensation. Design of I-PD control is far simpler than PID because the former is based on more natural idea of compensation.

The design method is easily extendable to sampled-data (i.e. discrete-time) control system design, including the continuous-time control as a special case of sampling period equal to zero. The method is also extendable to smooth nonlinear control system design, where either denominator-expanded-form of an extended nonlinear transfer function or, equivalently, differential equation expression can be used.