Chapter 17
Comparison of Control Strategies by the Example of the Cooling Fan Control of a Mobile Machine

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ABSTRACT

In order to compare different control strategies, the cooling system of a mobile machine has been chosen. The example control problem was to run the cooling system for m control variables and with n≤m correction variables in a way to minimize power in order to save energy and to reduce fan noise while maintaining sufficient cooling. The plant is nonlinear. Three different kinds of controllers have been investigated in several variations (i.e. fuzzy control, PI[D], and Model Predictive Control [MPC]). Fourteen different criteria have been used in this chapter for evaluation. In many respects, a linear controller with fuzzy prediction proved best, in particular the prediction model can handle nonlinear properties of the plant.

INTRODUCTION

Beside classic PI and PID controllers today a lot of other controller concepts are known. Some of them, i.e. fuzzy controllers and model predictive controllers, which can be implemented in present embedded electronic control units without reaching their limits are used in a specific example application. This example application is the cooling system of a dumper, a construction machine which can be considered as a motorized wheelbarrow. The cooling controller does not act directly upon engine control, indirect effects, e.g. a reaction of the engine controller to overheating due to insufficient cooling, are possible. The controlled plant is not linear. Mathematically spoken the plant is the relation between the demanded fan power as plant input and the resulting temperatures of coolant, lubricant, hydraulic oil and inlet air

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under different working conditions as plant output. Such plants are typical situations in which control is implemented without identification of the system, i.e. without mathematical modeling. Identification is not impossible with nonlinear systems, but the effort is large and the resulting accuracy often disappointing. There are a lot of requirements, so a controller has to react quickly to disturbances or changing setpoints and the controlled variable should stay closed to its setpoint. Not everything which is mathematically possible is also reasonable from a practical point of view, so beyond formal requirements other requirements concerning the industrial usability of a controller need to be considered, these requirements might be in practice even more crucial for the choice of a controller than its mathematical properties.

The PI(D), fuzzy and predictive controllers have been investigated under different scenarios on a validated laboratory model of the plant which uses the original embedded control unit of the machine. In this setup all controllers have been subject to the same conditions showing weakness and strength of each controller. A long catalogue of different criteria to evaluate the different properties of controllers is proposed, the reader might cancel items which seem not relevant to his applications. Based on this set of criteria a decision is made which concept proves best. Finally a generalization to other problems is given.

BACKGROUND

PID Control

The probably oldest kind of linear controllers is a proportional controller (P controller) which generates a control action $u(t)$ proportional to the error $e(t)$, i.e. the deviation of the controlled variable from the reference. To eliminate the permanent remaining error $e(t \to \infty)$ of a proportional control an integrator can be switched in parallel to the proportional controller, this combination is called a PI controller. In order to accelerate the response of the controller an additional differentiator can be switched in parallel to the PI controller, this combination is called a PID controller. Let $u(t)$ be the variable manipulated by the controller, so a PID controller is defined in time domain by

$$u(t) = K_P e(t) + K_I \int_0^t e(\tau)\, d\tau + K_D \frac{de(t)}{dt}, \tag{1}$$

where K_P, K_I and K_D are proportional, integral and differential coefficients and τ is the integrator time. In frequency domain the Laplace transform of (1) yields the transfer function

$$G(s) = K_P + K_I \frac{1}{s} + K_D s, \tag{2}$$

with $s = e^{(j\omega+\sigma)t}$.

PI controllers and PID controllers are the standard tools of control engineering, because they can be easily realized as analogue electronic circuits with operational amplifiers or today as computationally efficient and amazingly simple software code on microcontrollers.

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