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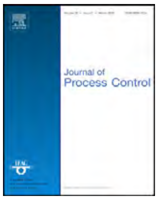

A systematic way to extend ideal PID tuning rules to the real structure

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ABSTRACT

Tuning an ideal PID and then using its parameters in a real one, can yield undesired results. Nonetheless, many rules conceived for the ideal PID are successfully used in practice, owing to their greater flexibility. A systematic method would thus be useful to *extend* ideal PID tuning rules to the real PID, so as to preserve said flexibility while synthesising a realistic controller. This manuscript proposes a simple solution, and some examples to witness its validity.

1. Introduction

Despite the number of PID tuning methods and tools available in the literature [1] and in the applications [2], several studies indicate that most installed PIDs have the derivative part switched off [3]. In the authors' opinion, one reason is that many rules do not exploit that part satisfactorily because they were originally conceived for the *ideal* PID, i.e., without accounting for the so called "derivative filter". Quite obviously the matter was already addressed: [4] reports a methodological discussion, while tuning rules for the real PID are treated for example in [5–7]. Nonetheless, methods for the real PID are still a minority, and in most industrial autotuners the derivative filter is merely introduced *a posteriori* [2].

This work proposes an alternative perspective: instead of deriving *ad hoc* rules for the real PID, rules conceived for the ideal PID are *extended* to the real one, based on objective considerations. Extreme simplicity is sought, so that the obtained extensions can be used also in low-end devices, provided that the derivative filter can be adjusted. When this is not the case, if some CAD-like design tool is available, the user can always build up a real PID by composing blocks of the "transfer function" type, thereby creating his/her own regulator with adjustable filter, and taking profit of the presented proposal.

The manuscript is organised as follows. Section 2 motivates the proposed approach by showing (also via a minimal literature review) that methods for the ideal PID not only are easier to devise, but also generally exhibit more flexibility as for the attainable tuning goals; tradeoffs between different objectives are a matter of increasing importance, as recently witnessed e.g. by [8]. Based on said considerations, Section 3 presents the *rationale* of the proposed extension methodology, and then employs that *rationale* to derive some extension techniques, applied in Section 4 to some ideal PID tuning rules. By means of suitable examples, Section 4 also demonstrates that the extended rules preserve the flexibility of the original ones, while avoiding the potential pitfalls of an improperly tuned derivative filter. Finally, Section 5 gives some concluding remarks and sketches out future research.

2. Motivation and brief literature review

In the one-degree-of-freedom (1-dof) case considered here, the error-to-control transfer function of an ideal PID takes the form

$$R_{\text{ideal}}(s) = \kappa\left(1 + \frac{1}{s\tau_i} + s\tau_d\right), \tag{1}$$

while its real counterpart can be expressed, generally enough for this study, by the so called ISA form

$$R_{\text{ISA}}(s) = K\left(1 + \frac{1}{sT_i} + \frac{sT_d}{1 + sT_d/N}\right). \tag{2}$$

Conceiving tuning rules for (1) is apparently easier than for (2), basically because in (1) the denominator phase is fixed to -90°, while in (2) it depends on the derivative filter. A quick look at the literature permits however some further considerations, dividing the methods commonly employed into four classes.

Empirical methods start from some characteristic of a time-domain process response, and some assumption on the process dynamics. The PID is tuned by imposing the desired characteristics of the closed-loop system (e.g. the damping).

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