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IMC-like analytical $\mathcal{H}_\infty$ design with S/SP mixed sensitivity consideration: Utility in PID tuning guidance[☆]

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ABSTRACT

This article presents an $\mathcal{H}_\infty$ design that alleviates some difficulties with standard Internal Model Control (IMC), while still obeying the same spirit of simplicity. The controller derivation is carried out analytically based on a *weighted sensitivity* formulation. The corresponding frequency weight, chosen systematically, involves two tuning parameters with clear meaning in terms of common design specifications: one adjusts the *robustness/performance* trade-off as in the IMC procedure; the other one balances the *servo* and *regulatory* performance. For illustration purposes, the method is applied to analytical tuning of PI compensators. Due to its simplicity and effectiveness, the presented methodology is also suitable for teaching purposes.

1. Introduction

Simplicity is a desired feature of a control algorithm: we would like it to be widely applicable and easy to understand, involving as few tuning parameters as possible. Ideally, these parameters should possess a clear engineering meaning, making the tuning a systematic task according to the given specifications. As for implementation, low-order controllers are preferable.

In this line, the Proportional-Integrative-Derivative (PID) controller is recognized to be the bread and butter of automatic control, being by far the most dominating form of feedback in a wide range of industrial applications [3,20]; the PID strategy is particularly effective in process control, where a combination of benign process dynamics and modest performance requirements finds its place. The ideal PID law is based on the present (P), past (I) and estimated future (D) error information. In accordance with this original conception, there are only three tuning parameters. Even for such a simple strategy, it is not easy to find good settings without a systematic procedure [15,17,21].

During the last 20 years, there has been a revived interest in PID control, motivated by the advent of model predictive control, which requires well-tuned PID compensators at the bottom level, and the emergence of auto-tuning tools [2]. As a result, numerical (optimization-based) techniques have been suggested in the literature [3,24,26,29]. In the same vein, analytically derived tuning rules have appeared [9,13,19,25]. Another reason for the PID revival has been the lack of results regarding stabilization of delayed systems [10,16,20,23]. These research efforts, specially the trend for analytical design, has incorporated into the PID arena the control theory mainstream developments, leaving aside more specific techniques.

Among the analytical methods, IMC [14] has gained remarkable industrial acceptance due to its simple yet effective procedure [6,21]. Internal Model Control theory was first applied to PID control of stable plants in [18], solving the robustness problems associated with some early tunings like [30]. Although the IMC-PID settings [18] are robust and yield good set-point responses, they result in poor load disturbance rejection for integrating/lag-dominant plants [5,11]. Alternative PID tuning rules aimed at good regulatory performance can be consulted in [11,19]. In [21], remarkably simple tuning rules which provide balanced servo/regulator performance are proposed based on a modification of the settings in [18]. It is important to realize that the problems with the original IMC-based tunings come indeed from inherent shortcomings of the IMC procedure, thoroughly revised in [6].

The purpose of this article is to present an $\mathcal{H}_\infty$ design which avoids some of the limitations of the IMC method, while retaining its simplicity as much as possible. In particular, the method is

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