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Simultaneous automated design of structured QFT controller and prefilter using nonlinear programming

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SUMMARY

This paper describes a nonlinear programming-based robust design methodology for controllers and prefilters of a predefined structure for the linear time-invariant systems involved in the quantitative feedback theory. This controller and prefilter synthesis problem is formulated as a single optimization problem with a given performance optimization objective and constraints enforcing stability and various specifications usually enforced in the quantitative feedback theory. The focus is set on providing constraints expression that can be used in standard nonlinear programming solvers. The nonlinear solver then computes in a single-step controller and prefilter design parameters that satisfy the prescribed constraints and maximizes the performance optimization objective. The effectiveness of the proposed approach is demonstrated through a variety of difficult design cases like resonant plants, open-loop unstable plants, and plants with variation in the time delay. Copyright © 2016 John Wiley & Sons, Ltd.

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KEY WORDS: quantitative feedback theory; controller and prefilter synthesis; nonlinear programming

1. INTRODUCTION

Most of the real-world systems are uncertain because of external disturbances and measurements noise. Because of this uncertainty, there are always mismatches between mathematical models and actual real systems. Robust control design techniques are well suited for this kind of uncertain systems. Because of its usefulness, the automation of robust controller and prefilter designs is of key concern in the control community [1]. Quantitative feedback theory (QFT), introduced by Isaac Horowitz, is one such frequency domain technique that uses Nichols charts in order to achieve a desired robust design over a specified region of uncertainty in the plant parameters [2]. It uses a two-degree-of-freedom structure as shown in Figure 1. The main objective of QFT is to find the controller and prefilter transfer functions that guarantee the system performance specifications over the range of plant uncertainties and over the range of design frequencies.

Quantitative feedback theory design technique uses phase information in the design process and it is highly transparent to see design trade-offs at each design frequency. QFT consists of design steps like bound generation and controller and prefilter synthesis using loop-shaping methods. The automation of loop-shaping is of great interest because even for a skillful person, it becomes very tedious and time-consuming for complex systems.

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