9b Computational Approach for Adjudging Feasibility of Acceptable Disturbance Rejection

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The achievable control quality ("controllability") is limited by the plant itself, independent of the controller design algorithm. A key issue in the controllability analysis is to decide upfront if there exists a controller that can reduce the effect of disturbances to an acceptable level with the available manipulated variables. When such a controller exists, the process is said to have "operability" (Georgakis et al., 2004). A closely related problem is that of steady-state "flexibility" (Swaney and Grossman, 1985). In this paper, we consider the following problem posed by Skogestad and Wolff (1992):

Is it possible to keep the outputs within their allowable bounds for the worst possible combination of disturbances, while still keeping the manipulated variables within their physical bounds? With proper scaling of the variables, the problem if it possible to keep $|y(t)| < 1$ with $|u(t)| < 1$ for all $|d(t)| < 1$.

Within the past decade, a number of papers, which provide partial solutions to this problem, have appeared in the literature. The most notable contributions are from Hovd and co-workers, who solved a steady-state version (Hovd et al., 2003) and also recently a frequency-by-frequency version of this problem (Hovd and Kookos, 2005). They used a signal-based approach, which results into a non-convex program and the solution is computationally expensive.

In this paper, we provide a complete solution to the dynamic version of this problem for linear systems, under the additional but reasonable assumption that the controller is linear and causal. Using a transfer-function approach, it is shown that the problem can be posed as an L1-optimal controller design problem (Dahleh and Diaz-Bobillo, 1995). This framework encompasses non-minimum phase and also unstable plants. The resulting optimization problem is a semi-infinite linear program. Truncated versions of this problem with guaranteed convergence can be solved easily using off-the-shelve software. The computational requirements can be reduced further using duality theory. The proposed solution can be easily extended to handle some related problems, e.g. minimum control effort required for acceptable disturbance rejection.

References

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