Fixed-Order Sparsity Promoting H_2-Conic Control

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Abstract: Large-scale systems are ubiquitous in many fields such as robotics, power systems, and machine learning. These systems often require disturbance rejection to operate at high performance standards. Standard H_2-optimal controllers achieve excellent disturbance rejection but cannot offer robust stability guarantees in the presence of communication delays, parametric uncertainty, or nonlinearities. Further, these centralized and full order controllers are impractical to implement due to bandwidth limitations and finite computational capacity. Sparsity promotion has recently addressed this latter issue by designing sparsely communicating distributed controllers, and passivity-based control has found wide utility in providing robust nonlinear stability. However, passivity is frequently violated in practical applications, and sparsity promoting design has not yet been reconciled with robust control.

This work provides sparsely communicating distributed disturbance rejection and nonlinear stability guarantees by combining sparse controller design and conic-sector-based design. Zames' conic sectors are an input-output plant description that generalizes passivity to more practically realizable systems, and the associated Conic Sector Theorem establishes closed-loop input-output stability from open-loop properties. In the proposed problem, the closed-loop H_2-norm and controller communication density are jointly minimized while the controller is constrained to satisfy prescribed conic bounds. The controller is assumed to be LTI dynamic output feedback of arbitrary dimension n_c. This NP-hard problem is made tractable by substituting the cardinality operator with the weighted l_1 norm and using the Conic Sector Lemma and iterative convex overbounding to pose a convergent series of convex semidefinite programs that iteratively improve controller performance while increasing sparsity. This allows reduced-order, structured design and improves performance from previous conic designs. Further, though the design problem is centralized, chordal decomposition techniques reduce the problem's iteration complexity from $O(n^6)$ to nearly $O(n^3)$ for valuable special cases, potentially without significant reduction in controller performance. These developments make distributed H2-conic control design computationally competitive with more conservative decentralized techniques.

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