論文の内容の要旨

H_2 Control Performance Limitations for SIMO Feedback Control Systems

（SIMO フィードバック制御系に対する H_2 制御性能限界）

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This thesis is devoted to a research area that studies the fundamental performance limitation and trade-off of feedback control, a subject intensively developed in the linear time-invariant feedback systems, beginning with the classical work of Bode in the 1940s on logarithmic sensitivity integrals. In modern control design, the studies on performance limitation serve as an appendage tool since they help a control system designer specifies reasonable control objectives, and understands the intrinsic limits and the trade-off between conflicting design considerations.

In this thesis we quantify and characterize the fundamental performance limitations arise in H_2 optimal tracking and regulation control problems of single-input multiple-output (SIMO) linear time-invariant (LTI) feedback control systems. In tracking problem, the control performance is measured by the tracking error response, possibly under control input constraint, with respect to a step reference input. While in regulation problem, the performance is measured by the energy of the control input simultaneously with that of the system output and sensitivity constraints, against an impulsive disturbance input.

Our primary interest is not on how to find the optimal or robust controller. Rather, we are interesting in relating the optimal performance with some simple characteristics of the plant to be controlled. In other words, we provide the analytical closed-form expressions of the optimal performance in terms of dynamics and structure of the plant. The analytical expressions, however, constitute guidelines for designing an easily controllable plant in practical situations, from which the control system designer may rely in determining the optimal design parameters and reasonable control strategies.

We mostly focus our attention on tracking and regulation problems of discrete-time systems. Toward the existing results of continuous-time systems, we make small corrections and perform a few extensions. We then reformulate and resolve both problems in delta domain. An analysis on the continuity property shows that we can completely recover the continuous-time expressions from the delta domain expressions stand point as sampling time approaches zero. Frankly speaking, we provide comprehensive and unified expressions on the characterization of the control performance limitations in the H_2 tracking and regulation problems. Furthermore, our analytical expressions show that the optimal tracking and regulation performances are

explicitly characterized by the plant's non-minimum phase zeros and unstable poles as well as the plant gain. We confirm the effectiveness of the derived expressions by several illustrative examples. We also show how to apply the analytical expressions to practical applications including the control of three-disk torsional system, inverted pendulum system, and magnetic bearing system. In addition, by invoking our linear time-invariant results we provide the analytical closed-form expressions of the optimal tracking performance for sampled-data systems and the optimal regulation performance for delay-time systems.