H_∞ Control and its Applications

By Ben M. Chen

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Intensive research efforts have been made for active/hybrid control of civil engineering structures subject to severe wind gusts and earthquakes. Various advanced control theories, including H_2 control, H_∞ control, sliding mode control, optimal polynomial control, etc., have been investigated and proposed for applications to civil engineering structures. Full-scale in situ structures involve considerable uncertainties in the parameters of the system as well as external excitations. Not only is a precise estimation or measurement of structural properties difficult, but also the degradation of these properties with time cannot be determined with confidence. Hence, the capability of a control method to guarantee robustness is very important for practical implementations of active control systems. A controller designed by ignoring or simplifying uncertainties in parameters and excitations may not perform in the desired fashion in actual applications. The basic philosophy of H_∞ control is to design a controller for the worst case scenario, i.e., paying the price of increased sensitivity over a large frequency bandwidth to reduce sensitivity at a frequency with the largest peak in the transfer function. This control method has the ability to treat plant modeling errors and unknown disturbances. Fig. 1 shows a typical representation for the control of an uncertain system with a linear system block **P** and an uncertainty block Δ. A representative H_∞ disturbance rejection control problem is to find a controller **U** such that the H_∞ norm of the transfer function from disturbance **W** to output **Y** is less than a given disturbance attenuation level $\gamma > 0$. Obviously, the solution for a desirable controller **U** depends on the property of the uncertainty Δ and the desired disturbance attenuation level γ, and its existence condition is expressed as LMI (linear matrix inequalities) in general.

The book reviewed herein deals with fundamental aspects of H_∞ control theories, e.g., computation of the infimum of the H_∞ norm as well as theories to design full-state feedback, full-order output feedback, and reduced-order output feedback controllers in continuous and discrete time using a particular approach, developed by the authors, whereby a controller is designed by finding γ without iteration. The noniterative solution of the H_∞ controller is obtained because this approach considers a certain system, i.e., where the uncertainty Δ is zero. It is not an introductory textbook for students on H_∞ control, but rather a well-written monograph on the restricted area of designing H_∞ controllers by finding γ without iteration. The organization of the book is as follows. The problem statements for the H_∞ control methodology and the mathematical preliminaries, including the special coordinate basis, are discussed in Chapters 1 and 2, respectively. The existence conditions of the H_∞ control methodology are recalled shortly without proofs in Chapter 3, and its mapping between a continuous-time and a discrete-time system using bilinear transformation is described in Chapter 4. Chapters 5–7 describe the design of H_∞ controllers for continuous-time systems. A noniterative method to compute the infinimum, γ^*, of the H_∞ norm of the closed loop transfer function is described in Chapter 5. In Chapter 6, a method is presented to obtain the closed form of the γ suboptimal full-state/output feedback control with a tuning parameter. The H_∞ almost disturbance decoupling problem is addressed in Chapter 7. The theories discussed in Chapters 5–7 are extended to the case of design of an H_∞ controller for discrete-time systems in Chapters 8–10. Finally, two practical examples for the design of H_∞ controllers are discussed in Chapters 11 and 12.

The application of theories presented in Chapters 1–9 is illustrated through simple numerical examples. These examples are quite helpful in simplifying the understanding of this particular area of the H_∞ control theory. Further, the examples given on design of a piezoelectric actuator with nonlinear hysteretic behavior and a gyro-stabilized mirror targeting system with nonlinear coupling between different degrees of freedom are similar to many nonlinear civil engineering systems, and they serve as a good tutorial for interested civil engineers. This book will help in building a thorough understanding of recent developments in H_∞ control theory and is recommended for people familiar with fundamental aspects of structural control, and who have undergone graduate level courses in linear systems and multivariable control theories.

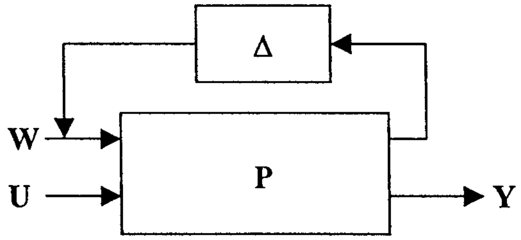

FIG. 1. Block Diagram of Uncertain Linear System

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