Robust Control of Uncertain Nonlinear Systems

Final Report for ONR Young Investigator Award

John C. Doyle
Professor
Electrical Engineering
Caltech 116-81
Pasadena, CA 91125
(818) 395-4808
doylehot.caltech.edu
Highlights

Substantial progress in a number of directions occurred during this program. Professor Doyle organized a 2-day workshop preceding the 1987 ACC on the subject of this program, with about 70 attendees. Several papers at the 1987 ACC reported on progress in nonlinear control (Doyle, Smith, and Enns, 1987 and Doyle and Packard, 1987), and robust control with an $H_2$ performance objective (Packard and Doyle, 1987). Progress has been made since on combining $H_2$ and $H_{\infty}$ performance objectives, (Doyle, Zhou, and Bodenheimer (1989)).

New results on $\mu$ were reported at the 1988 ACC in Packard and Doyle, (1988) and Fan, Tits, and Doyle, (1988). Later, new methods for the computation of Structured Singular Values (SSV or $\mu$) were developed based on Packard, Fan, and Doyle (1988), Fan, M., A. Tits, and J. Doyle (1990) and Young and Doyle (1990), with especially exciting results for the real-parameter case (Young, Newlin and Doyle (1991)). Work continued in extending the $\mu$ framework in directions that should lead to more effective methods for system identification (Newlin and Smith (1991)).

Progress has also continued on basic $H_{\infty}$ theory. New state space formulas were obtained for $H_{\infty}$ optimal controllers that dramatically simplify both the theory and computation (Doyle, Glover, Khargonekar, and Francis, 1988 and Glover and Doyle, 1988, and Doyle, Glover, Khargonekar, and Francis (1989)). A new characterization of $H_{\infty}$ optimal controllers gives insight into their relationship with classical control methods (Lenz, Khargonekar, and Doyle, 1988).

Several new results were obtained extending standard analysis techniques to Linear Fractional Transformations (LFT) using Structured Singular Value, $\mu$, and Linear Matrix Inequalities (LMI) in solving LFT problems. LFTs and LMIs play a very important role in postmodern control theory by providing a framework that unifies many concepts and generalizes transfer functions and their state-space realizations to include uncertainty. Doyle, Zhou, and Packard (1991) reviews known results on robust stability and performance and establishes a common and unified framework for the companion papers, which consider generalizations and extensions of balanced realizations and model reduction (Wang, Doyle, Beck, and Glover, 1991), stabilization (Lu, Zhou, and Doyle, 1991), optimal control (Packard, Zhou, Pandey, and Becker, 1991), mixed real/complex $\mu$ (Young, Newlin and Doyle, 1991), model validation (Newlin and Smith, 1991), and LMI computation (Beck, 1991).

On the application front, a case study session was organized for the 1987 IFAC World Congress in Munich. Papers included a review of $\mu$-based theory (Doyle, 1987) and its application to a process control problem (Smith, Doyle, Morari, and Skjellum, 1987). Additional applications were presented at the 1988 ACC (Balas and Doyle, 1988 and Smith and Doyle, 1988). All of these applications involved actual implementations using laboratory experiments. Applications papers on distillations columns (Skogestad, Morari, and Doyle (1989)) and flexible structure (Balas and Doyle (1989)) were also published.
Awards and publications

Awards

Two papers received major awards during this program. Doyle, Glover, Khargonekar, and Francis (1989) received the Axelby Prize from the IEEE Control System Society for the outstanding paper in the IEEE Transactions on Automatic Control and the IEEE W. R. G. Baker Outstanding Paper Award. The latter award is for the best paper reporting original research results in all of the IEEE publications, and it is the first time the award has been given to a paper in the controls area. Skogestad, Morari, and Doyle (1988) also won the Axelby Prize.

Publications

Journals


Books

Conference proceedings


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