25 YEARS AGO

In this issue, "25 Years Ago" revisits the article "Dynamic Scheduling of Modern-Robust-Control Autopilot Designs for Missiles" by Robert T. Reichert in *IEEE Control Systems Magazine*, vol. 12, no. 5, pp. 35–42, 1992. Below is an excerpt from the article.

This article examines dynamically scheduling multiple linear-time-invariant (LTI) controllers, designed using H_∞/μ techniques, for systems with widely varying plant dynamics. The observer/full-state feedback structure of the LTI H_∞ controller is extended to accommodate the time-varying, nonlinear dynamics problem. A procedure for handling the variations that occur between fixed operating points, in the two-Riccati equation solutions, is proposed. An example missile control problem, that contains realistic and necessary performance goals and robustness constraints, is included to demonstrate the viability of this new approach.

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CHALLENGING PROBLEM

Wide variations in plant parameters coupled with significant constraints on controller bandwidth make the design of autopilots for highly-agile missiles a challenging problem. Most design techniques approach this problem by selecting a finite number of fixed operating points about which the plant model is linearized. For each linearization a linear-time-invariant (LTI) controller is obtained, which in the local region of the fixed operating point delivers the desired performance characteristics. However, as conditions depart from this local region the variations in the plant dynamics become large enough to degrade performance and stability when using the fixed LTI controller. To facilitate operation for a dynamically varying plant, designers resort to ad-hoc gain scheduling techniques.

The complexity of the gain scheduling is highly dependent upon the

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include the Outstanding Paper Award from the IEEE (1998); the American Automatic Control Council's O. Hugo Schuck Best Paper Award (2003); the ASME Division of Dynamic Systems, Measurement, and Control's Outstanding Investigator Award (2002); and the ASME Journal of Dynamic Systems, Measurement, and Control Best Paper award (1983 and 2001).

Prof. Hedrick supervised more than 70 Ph.D. students and mentored countless others, including undergraduate students, M.S. students, post-doctoral fellows, and visiting scholars. He was famous for his clarity of exposition, design-oriented teaching, and ability to explain complicated topics in lucid and insightful ways.

He was a competitive tennis player, a Big 10 champion while at Michigan, and competed in major U.S. and European Open tournaments in his youth. He sometimes joked he "had been good enough to lose to some very good players in three U.S. Open tournaments." He played tennis competitively in the master's category until just before his death.

Prof. Hedrick was devoted to his family and was a role model for work–life balance.

Prof. Hedrick was devoted to his family and was a role model for work–life balance. His family always took priority, and he spoke very fondly of time spent with his daughters, their accomplishments, coaching their sports teams, and family vacations.

He is survived by his wife Carlyle; daughters Ashley, Tristan, and Ryan and their husbands; and three grandchildren.

We remember Karl for his wisdom, generosity, kindness, sense of humor, steady guidance, and his extraordinary calm under pressure. He treated his students like family. He will be greatly missed.

Andrew Alleyne
Joseph Beaman
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structure of the LTI controllers at each fixed operating point. At one extreme of complexity, the structure of the LTI controller dynamics may be fixed for each operating point with only one or a few gains varying with changing plant and operating condition parameters. This is often the case when classical control techniques are applied to the design of the LTI controller. On the other end of complexity each LTI controller may have a different state order and feedback topology. This case may occur as a result of applying some of the popular multivariable, state-space design procedures. In this latter case, the gain-scheduling implementation considerations may become a serious impediment to the use and acceptance of these multivariable design approaches.

This paper begins with a brief review of some pertinent modern-robust control theory fundamentals for LTI systems. This material is drawn from References [1], [2], [10], [11]. This is followed by an overview of the LTI synthesis technique and the proposed technique for dynamically scheduling a set of LTI controllers. The proposed technique is applied to an example missile autopilot design and sample results shown.

DYNAMIC SCHEDULING TECHNIQUE

A dynamic scheduling technique for robust control designs has been proposed. The technique extends the underlying estimator/state-feedback structure of the LTI controller to include nonlinear, time-varying dynamics in combination with a gain-scheduling approach for the solutions to the 2-Riccati equation solutions. This technique has been successfully demonstrated for a missile autopilot design example.

REFERENCES

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