Workshop Title: New Developments In Robust and Adaptive Control : Adaptive OBLTR

Presenters: Dr. Kevin A. Wise, Dr. Eugene Lavretsky
The Boeing Company

(i) topic, rationale, and format (full-day or half-day);

This is a 4 Hr (half-day) workshop.

Goal: To teach new developments in output feedback robust and adaptive control theory to uncertain, nonlinear systems, with examples used from advanced aerospace applications.

Textbook: *Robust and Adaptive Control with Aerospace Applications*, Lavretsky, Wise, Springer Verlag, 2013.
Workshop fees to include text book.

(ii) list of presenters, along with biographical sketches and short abstracts of presentations;

Presenter 1: Kevin A. Wise, (B.S. 1980, M.S. 1982, Ph.D. 1987) - is a Senior Technical Fellow, Advanced Flight Controls, in the Boeing Phantom Works. Since joining Boeing in 1982, he has developed vehicle management systems, flight control systems, and control system design tools and processes for advanced manned and unmanned aircraft and weapon system programs. His research interests include intelligent autonomy, aircraft and missile dynamics and control, robust adaptive control, optimal control, and robustness theory. He has authored more than 70 technical articles, and has taught graduate level control theory since 1987 at Washington University in St. Louis, Southern Illinois University at Edwardsville, and at the University of Missouri Science and Technology. He is an IEEE Fellow, and Fellow of the AIAA.

Eugene Lavretsky, (M.S. 1983, Ph.D. 1999) – is a Boeing Senior Technical Fellow, working at the Boeing Research & Technology in Huntington Beach, CA. During his career at Boeing, Dr. Lavretsky has developed flight control methods, system identification tools, and flight simulation technologies for transport aircraft, advanced unmanned aerial platforms, and weapon systems. His research interests include robust and adaptive control, system identification and flight dynamics. He has written over 100 technical articles, and has taught graduate control courses at the California Long Beach State University, Claremont Graduate University, California Institute of Technology, University of Missouri Science and Technology, and at the University of Southern California. Dr. Lavretsky is an Associate Fellow of AIAA and a Senior Member of IEEE. He is the recipient of the AIAA Mechanics and Control of Flight Award (2009), the IEEE Control System Magazine Outstanding Paper Award (2011), and the AACC Control Engineering Practice Award, (2012).

This is a two-part workshop that covers robust control, used to form a baseline control, and adaptive control, used to extend the baseline control system's robustness and performance under uncertainties. Both state feedback and output feedback architectures are presented.

Part I begins with an introduction to challenges in control design, analysis, and simulation of manned and unmanned aircraft. General aviation background and current trends that lead to the need for more advanced control are discussed. Also presented is a brief survey of control-theoretic methods for existing and future aircraft. The theoretical portion of Part I starts with the introduction of robust and optimal linear control methods for linear systems. Command tracking using linear quadratic regulators (LQR) with integral action is presented. This part also covers two output feedback design methods, such as projective control and linear quadratic Gaussian control with Loop Transfer Recovery (LQG/LTR). These algorithms are employed to develop a baseline control architecture. New developments in observer-based architectures, called observer-based loop transfer recovery (OB-LTR), asymptotically achieves positive real system behavior at certain loop break points during recovery. This workshop will present design insights into using this method for flight control design problems, including systems using acceleration feedbacks that are nonminimum phase. During the design process the observer is artificially squared-up. This adds fictitious inputs to make the number of controls equal the number of measurements, and makes the observer design model minimum phase. This step is central to achieving the positive real behavior during recovery. To place the zeros in a desired location during plant squaring, an LQR or pole-placement algorithm can be used. Tutorial design examples will be covered to highlight this new design approach.

Part II begins with self-contained material on the design and analysis of adaptive state feedback controllers for linear and nonlinear uncertain dynamical systems in continuous-time domain. An overview of Lyapunov stability theory is given, followed by theoretical fundamentals for MRAC systems. Next, approximation properties of artificial neural networks and their applications to the design of direct adaptive systems are introduced, and several approximation-based MRAC methods are discussed. The part proceeds with the development of state feedback adaptive augmentation architectures for robust baseline linear controllers, followed by extensions and modifications to achieve transient performance in adaptive systems, as well as to accommodate output feedback constraints. In this part, we also present adaptive augmentation design methods to combine robust baseline controllers with adaptive feedback, focused on using the OB-LTR architecture.

(i) tentative schedule; and

Kevin Wise: first two hours
Eugene Lavretsky: Second two hours

(ii) target audience and expected enrollment.

Audience: Senior level and graduate students in control, professors, and practicing control engineers from all industries.

Last time our workshop had about 25 enrolled.