Controller Performance Evaluation of Fly-by-Feel (FBF) Technology

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Abstract for NARI Technical Seminar

Fly-by-feel (FBF) is a new paradigm for safely maximizing aircraft stability and performance across a wide range of conditions wherein the aircraft autonomously and intelligently senses the aerodynamic environment and efficiently adapts the aircraft structure and control surfaces to suit the current mission objectives. FBF depends on an integrated active approach to flight control, structural mode attenuation, and flow control. Desired flight performance, gust load alleviation and aerostructural stability in the presence of complex aeroservoelastic (ASE) model uncertainties are met by utilizing aerodynamic observables in a robust control law framework.

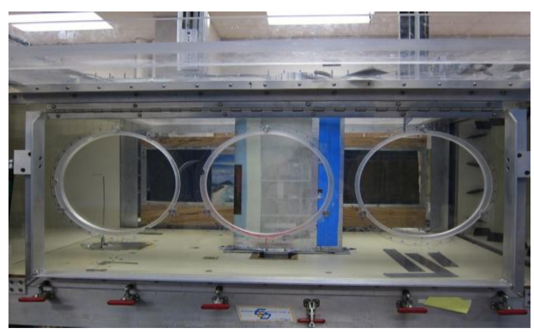
As opposed to conventional systems, flow bifurcation point sensors will be used as aerodynamic observables to estimate, in real-time without the delay of structural response, aerodynamic coefficients, which in turn will be used as direct aerodynamic force feedback for flight control resulting in minimization of ASE uncertainties. Sensors are integrated in a physics-based architecture that improves reliability, control effectiveness and robustness through a spatially distributed network, and this effort is a first step in showing feasibility. This wind tunnel test effort and data analysis provides for the first time a validation of the closed-loop control using aerodynamic observables for force feedback through flow bifurcation points. The resulting architecture will be scalable to flight.

The primary objective is to provide a technical basis for determining the extent of performance improvement of the FBF approach under operational flight conditions in comparison to conventional flight control systems. Secondary objectives include: (1) determining the relationship between aerodynamic observables with aeroelastic instabilities, loads/moments and control surface actuation in a nonlinear free pitch-and-plunge apparatus (PAPA) for a representative wing; (2) validating computational models predicting the aerodynamic coefficients (CL, CM & CD) based on pitch/plunge/actuator state and aerodynamic observables; (3) determining the accuracy/robustness of system identification techniques in capturing the nonlinear system parameters; and, (4) characterizing the performance of conventional and robust control laws using a variety of output for feedback including aerodynamic observables in unsteady flow.

To provide a basis for the next phase of the program, we (1) used a representative 2D wing with control surfaces instrumented with flow sensors, accelerometers and a load cell; (2) modeled the dynamic interactions and uncertainties in aerodynamics, structures, sensing and actuation, e.g., freeplay;; (3) designed control laws using the aerodynamic observables; (4) conducted open-loop/closed-loop wind tunnel tests in a free PAPA at TAMU (Texas A&M) to validate computational results; and, (5) conducted a post-test analysis of the control performance.

The next steps are to develop a closed-loop controller using leading-edge stagnation point as an output for feedback in unsteady flow conditions. Preliminary pitching tests have been conducted and are currently being analyzed. These tests provide a sound basis for the further development and validation of the use of flow bifurcation points for control feedback on actual flight test vehicles.

Results from this Seedling effort will be used to develop open-loop / closed-loop test procedures for upcoming tests on the F-18 with AFRL under the RASSCAL program, and follow-on NASA work in distributed aeroservoelastic control on the MUTT vehicle.



Instrumented wing at Texas A&M - free PAPA.

Wing instrumented at three span stations.