THE NASA F-15 INTELLIGENT FLIGHT CONTROL SYSTEMS – GENERATION II

Summary

The Second Generation (Gen II) control system for the F-15 Intelligent Flight Control System (IFCS) program implements direct adaptive neural networks to demonstrate robust tolerance to faults and failures. The direct adaptive tracking controller integrates learning neural networks (NNs) with a dynamic inversion control law. The term “direct adaptive” is used because the error between the reference model and the aircraft response is being compensated or “directly adapted” to minimize error without regard to knowing the cause of the error. No parameter estimation is needed for this direct adaptive control system.

In the Gen II design (fig. 1), the feedback errors are regulated with a proportional-plus-integral (PI) compensator. This basic compensator is augmented with an online NN that changes the system gains via an error-based adaptation law to improve aircraft performance at all times, including normal flight, system failures, mispredicted behavior, or changes in behavior resulting from damage.

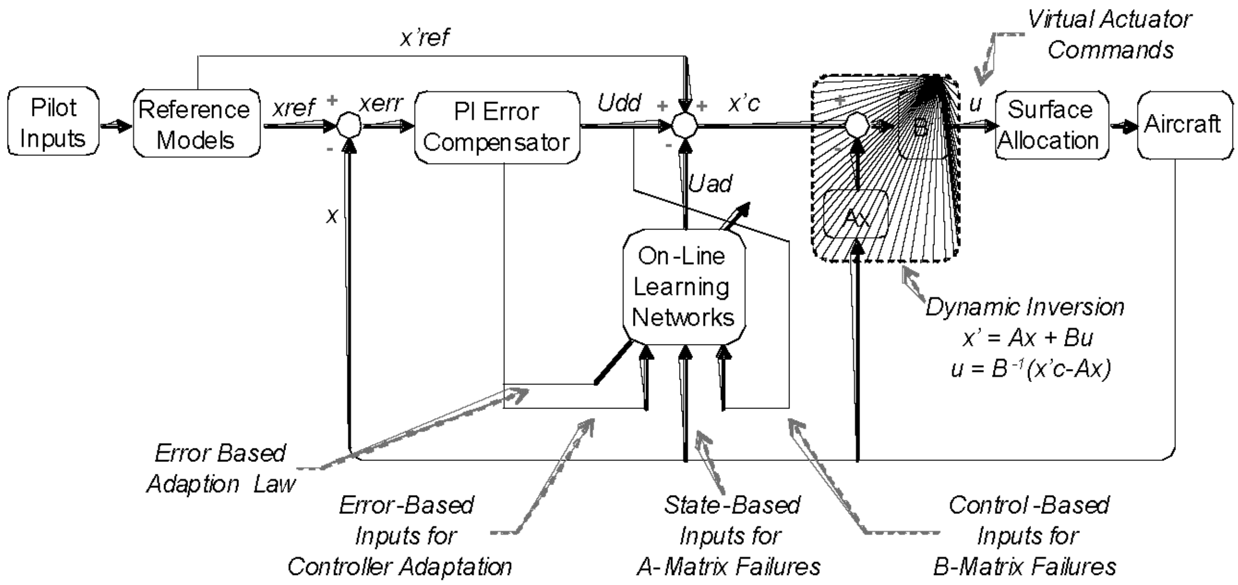

Figure 1. Direct-adaptive, neural network flight control.

Objective

The Gen II inflight performance shall be evaluated under both nominal configurations and in the presence of simulated surface failures (hold or bias).

Justification

Intelligent Flight Controls improves flight safety and mission completion for manned and unmanned vehicles. The technology can be applied to multichannel fly-by-wire control systems so that they can automatically compensate for off-nominal conditions, increasing aircraft performance over nonadapting control systems.

Approach

Flight performance comparisons will be made between Gen II controllers with and without the neural networks activated at the same conditions and in the presence of the same failures. Performance results will be evaluated against accepted handling qualities standards such as the Cooper-Harper Handling Qualities Rating Scale. All flight test conditions will be coordinated with simulation evaluations to validate in flight that the system performs as expected.

Failures are limited to those that can be accomplished safely (as determined by handling qualities and structural load considerations) in a subsonic flight envelope. No control surfaces will actually be failed; simulated failures will be implemented by software inserting a command to hold or bias surfaces at specified values. All simulated failure candidates will be pretested on a piloted simulation.

Results

Failures are designed to show controller adaptation to unknown aerodynamics (A matrix) and to control surface failures (B matrix). For A matrix failures, the symmetric canard command is biased by introducing a gain between 0.8 and –0.5. For B matrix failures, the right stabilator is held at trim, ±2° from trim, and ±4° from trim.

The NN architecture is designed to minimize transients upon failure introduction while improving tracking performance (fig. 2). The adaptation also reduces cross-axis coupling during the failure. Piloted simulations show notable handling quality improvements in the presences of failures.

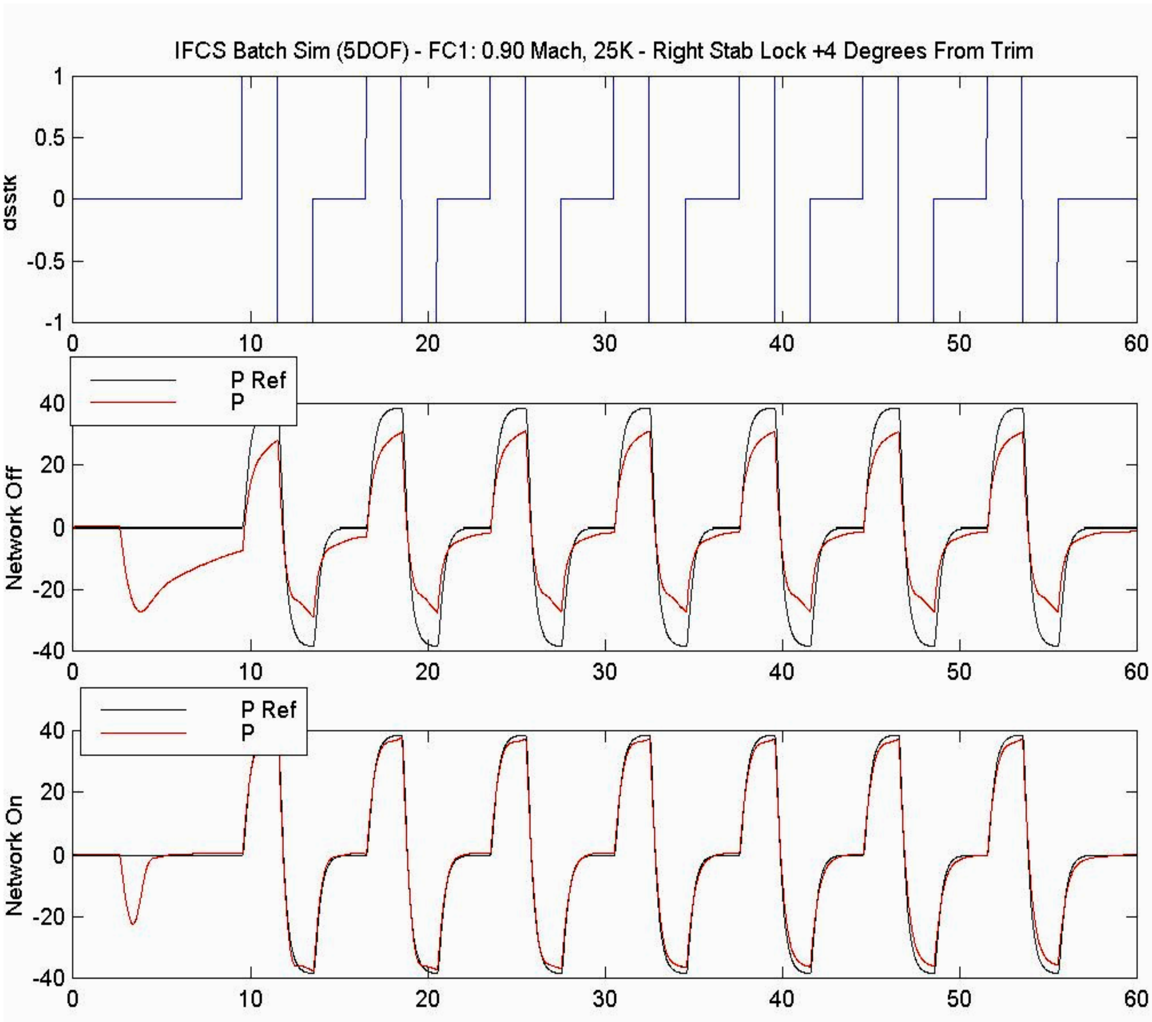

Figure 2. Improved roll performance example.

Status

The Critical Design Review was held in September, 2004, and the Gen II controller design is now complete. Onboard safety monitor software is nearing completion. Embedded software development is under way. Flight tests are expected to begin in September, 2005.

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