Simulation Based Evaluation of Integrated Adaptive Control and Flight Planning Technologies

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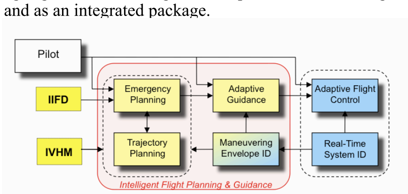
Integrated Resilient Aircraft Control

Objective

The objective of this work is to leverage NASA resources to enable effective evaluation of *resilient aircraft technologies* through simulation. This includes examining the strengths and weaknesses of adaptive controllers, emergency flight planning algorithms, and flight envelope determination algorithms both individually and as an integrated package.

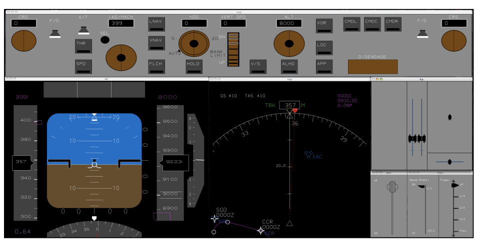


Intelligent /Adaptive Guidance, Navigation, and Control Architecture

NASA Unique Resources

FLTz (pronounced *Flight Z*)

- Desktop simulator developed in *C* and compatible with Fortran.
- Developed with GNU resources – i.e. no special software required.
- Macintosh/Linux/Windows compatible.
- Communication is performed through a global common variable structure that facilitates easy integration of new aircraft models (of arbitrary fidelity) and control architectures.
- Effective for rapidly testing new technologies and transitioning to ACFS.
- Simulations may be automated through scripting.



FLTz Desktop Simulation

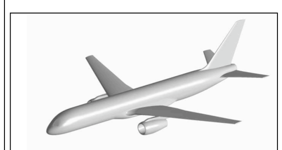
Advanced Concept Flight Simulator (ACFS)

- High-fidelity capable aircraft cockpit simulator that is entirely programmable
- Full 6 DOF motion base
- 180° horizontal and 40° vertical field of view
- Capable of displaying a wide variety of specific airports
- Highly programmable visualizations and displays.
- Capable of simulating a large number of aircraft
- Appropriate for full mission simulation with real pilots

ACFS Simulator – External View and Cockpit

GTM (Generic Transport Model)

- Aerodynamic model of a full-scale generic commercial transport aircraft
- Wind tunnel data collected for 5.5% dynamically scaled model
- Vortex Lattice Modeling used to generate various damage models
- Damages include losses to the left wing, left horizontal tail, and rudder
- Provides a uniform test bed for researchers to evaluate adaptive control and intelligent flight planning technologies
- Simulink based model under development
- Future work to include aeroservoelastic (ASE) effects and higher-fidelity engine model



Undamaged GTM

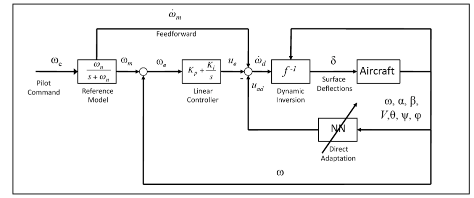
Considered GTM Damages

Current Technologies

Several technologies are currently integrated or in the process of being integrated with NASA's unique resources. Here is a quick snapshot of some of the technologies developed at NASA Ames.

Adaptive Flight Control Architectures

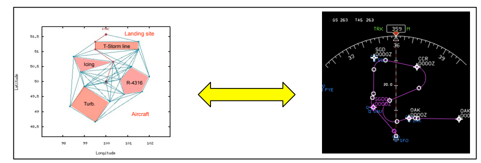
- Baseline model reference PI controller with dynamic inversion.
- Direct adaptive control using neural networks
- Hybrid indirect-adaptive control to update dynamic inversion model (recursive least squares based algorithm)
- Metrics-driven adjustment to neural network learning rate for both direct adaptive control and hybrid adaptive control
- Future work aimed at developing and integrating *L1* Adaptive Controller



Baseline Controller with Direct NN Adaptation

Emergency Flight Planning Algorithms

- Two tiered architecture featuring a high-level course planner and a low-level detailed trajectory planner.
- High level planner outputs a list of target waypoints to trajectory planning algorithm and a rank ordered list of possible landing sites.
- Low level trajectory planner constructs a kinematically feasible path using geometric primitives.



High Level Course Planner Communicating with Trajectory Planner

Work with NRA Partners

- Real-time identification of flight envelope (Ella Atkins, U. of Michigan)
- Flight envelope constraints used by planning algorithms

Experimental Plan

- Integrate all IRAC technologies into FLTz and ACFS.
- Have NASA test pilots perform preselected test maneuvers to evaluate adaptive controller performance using Cooper-Harper ratings.
- Collect and record flight data and evaluate controllers based on traditional control metrics, including **stability margins, transient performance**, **tracking performance**, and **cross-coupling**.
- Have NASA test pilots fly mission scenarios featuring a combination of flight conditions and delayed failures. Evaluate performance and value of emergency planning technologies and tools.

Conclusion

The NASA IRAC project is developing new state-of-the-art technologies for resilient aircraft control, guidance, and planning. Additionally, considerable effort is being placed on developing simulation capabilities for effective technology evaluation and maturation.

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