Tuning Multi-Loop Compensators to Meet Time and Frequency Domain Requirements

John Glass
Simulink® Control Tools Team
The MathWorks
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Presentation Overview

- Multi-loop control design
- Overview of multi-loop compensator design in Simulink®
- Guidance control system design using a Simulink model of an HL-20 lifting body
Multi-Loop Control Design

- Cascade Feedback Loops (Engine Control, Autopilot)

- Coupled Multi-Loop Control
Challenges of Multi-Loop Design

- Feedback structure may be fixed and controllers are distributed.
- Multi-Loop Design has inherent loop interaction effects.
- Many controllers are fixed structure, ex:

\[ G(s) = \frac{\tau_1}{s + \tau_1} \]
Application HL-20 Lifting Body

- Low cost re-entry vehicle
- Nose-first, horizontal, and unpowered landing
- Control system design tasks
  - Task 1: Flight control system design
  - Task 2: Guidance glideslope reference tracking and disturbance rejection
  - Task 3: Guidance yaw and roll corrections
  - Task 4: Landing gear control
HL-20 – Glideslope Control Problem

Goal: Build a feedback controller to control the height of the aircraft given the distance to the runway.

Desired Height

To Angle of Attack Command

Actual Height

Feedback Controller
Lateral Glideslope Regulation

- Flight path must remain within the cone
- Need to devise controller to reject the cross wind disturbance
- Nearing landing need to recover any roll angle for a clean landing

Use Roll to Bank Aircraft

Landing Cone to hit runway

Cross Wind

Automatic roll recovery at landing
Side Gust Control

- Build a bump-less transfer controller (A) to switch between
  - (B) Controlling the drift of the aircraft due to cross wind
  - (C) Recovering the roll angle at landing
Designing Compensators in Simulink® in R2006a

1. Build a control system in Simulink – model plant and layout control structure
2. From Simulink Control Design pick blocks to tune and auto-linearize model
3. Tune blocks using graphical design
   - One-click automated design
   - Interactive design
   - Simulink Response Optimization to meet time and frequency requirements
4. Write block parameters directly back to Simulink
Design Goals

- Robustness Requirement:
  - AoA Loop maintain a phase margin > 35 degrees
  - Phi Loop maintain a phase margin > 40 degrees
- Closed Loop Performance

**Height reference tracking**

![Diagram of height reference tracking](image)
Closed Loop Performance Goals

Disturbance rejection:
Side wind gust to lateral glideslope deviations

Cross Wind

Step Response

Amplitude

Time (sec)
Conclusions – Simulink Tools for Control Design

- New integrated workflow interface centered around Simulink in R2006a
- Build any control structure in Simulink and tune the compensators using these tools
- Tune multi-loop control systems in a single design environment
- Use graphical numerical optimization for compensator tuning, including frequency domain requirements