Header

Date: 03/11/2015
Location: UMore Park Airfield
Aircraft: Baldr
Pilot: Danny Chryst
Flights: 1 Baldr
Purpose: Testing the H-infinity controller designed to use only the split elevators for stabilization & tracking.

Weather

- Clear with average wind speeds of 2mph (SSE). Max wind speed of 6mph. Visibility 10 miles.
- METAR data from Lakeville (KLVN) and South Saint Paul (KSGS) reporting stations for the time period spanning the flight is given below.

Start

KLVN 111521Z AUTO 22001KT 10SM CLR 06/M01 A3032 RMK AO2
KSGS 111531Z AUTO 00000KT 10SM CLR 07/M03 A3033 RMK AO2 T00731027

Finish

KLVN 111621Z AUTO 14003KT 10SM CLR 08/M01 A3032 RMK AO2
KSGS 111631Z AUTO 11003KT 10SM CLR 10/M02 A3032 RMK AO2 T01021023

Introduction

Chris, Danny, Parul, and Raghu arrived at the UMore Park Airfield around 9am for the seventh, eighth, and ninth flights of Baldr.

Baldr is the UAV Lab's newest UltraStick 120 airframe that will be used for aircraft reliability research. Baldr is a modified UltraStick 120 airframe that has split elevators and split rudders, each surface driven by a dedicated servo motor. Recently, efforts have been underway at the University of Minnesota to design fault tolerant control laws for UAVs. Specifically, researchers have been focusing on attempting to control Baldr using only the split elevators, with all other control surfaces locked into their respective trim positions. The key idea in this experiment is controlling a conventional aircraft with two coplanar control surfaces. There are two main motivations that drove this experiment:

1. Exploring the controllability of conventional aircraft (with an empennage) that have been severely handicapped with losses in multiple aerodynamic control channels, and
2. Drawing meaningful conclusions about the controllability of two-surface flying wing aircraft which are subject to faults in any one of the two aerodynamic control surfaces.

For this experiment, the performance objectives were tracking phi and theta commands. Hence, only phi and theta tracking control loops were synthesized and implemented. It is important to note that each of the split elevators induce both longitudinal and lateral-directional motion in the aircraft. As a consequence, researchers were specifically interested in synthesizing multi-input, multi-output control

laws (as opposed to the conventional loop-at-a-time designs). For this experiment, researchers synthesized an H-infinity controller, with the primary performance objective being output regulation. A secondary performance objective was tracking phi and theta commands. The H-infinity controller was designed in Simulink and subsequently autocoded using Simulink coder. In addition, updated input trim settings for all the control surfaces (estimated from Baldr flights 1, 2, and 3) were used in this flight.

This experiment used both elevators of Baldr to regulate outputs around trim and track phi and theta. For the experiments where only one of the elevators of Baldr was controlled, please see flight report "20150311_BALDR_Flight7.pdf" and "20150311_BALDR_Flight8.pdf".

Experiment

A total of 11 runs were planned for this experiment. Only the first two runs were executed in this test. In all the runs, the baseline controller runs for the first five seconds to set up good initial conditions for the fault-tolerant H-infinity controller. At the end of the fifth second, the controller switches from baseline to H-infinity and the scheduled maneuver starts.

Run #	Maneuver	Duration [s]
1,2,3	Trimmed in straight & level flight at 23m/s. Pitch = 5deg. Roll = 0deg. Throttle = 65%.	30
4,5,6,7,8	Roll doublet of +/-10deg about trim roll attitude of 0deg. Maneuver started 6 seconds after autopilot initiation and lasted a total of 10 seconds.	16
9,10,11	Pitch doublet of +/- 5deg about trim pitch attitude of 5deg. Maneuver started 6 seconds after autopilot initiation and lasted a total of 6 seconds.	12

Observations

The overall tracking performance was poor. The flight test was stopped after the first two runs because of the unstable closed-loop response of the aircraft. For the first five seconds, the response of the closed-loop is well behaved because of the baseline controller. After the fifth second, once the controller switches over to H-infinity, the aircraft rolls to the right and pitches nose down. The pilot takes over control of the aircraft for safety reasons.

Flight code

    I.   Aircraft: Baldr
   II.   Guidance: guidance/guidance_1n2.c (3 straight & level, 5 roll doublets of +/-10deg, 3 pitch doublets of +/- 5deg)
  III.   Navigation: navigation/EKF_15state_quat.c
  IV.   Control: BALDR_TwoSurf_HINFDelayedCOLL/(autocoded C files)