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 left elevator 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 ONLY the left elevator of Baldr to regulate outputs around trim and track phi and theta. For the experiment where BOTH elevators of Baldr were controlled, please see flight report "20150311_BALDR_Flight9.pdf".

Experiment

A total of 12 runs were planned for this experiment. Only runs 1 through 5 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	Roll step of +10deg about trim roll attitude of 0deg. Maneuver started 6 seconds after autopilot initiation and lasted a total of 30 seconds.	36
7,8,9	Roll step of -10deg about trim roll attitude of 0deg. Maneuver started 6 seconds after autopilot initiation and lasted a total of 30 seconds.	36
10,11,12	Pitch doublet of +/- 5 deg 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 satisfactory. The flight test was stopped after the first five runs because concerning oscillations were seen in the closed-loop response of the aircraft.

1. Straight & level flight: the controller is able to regulate phi and theta to within +/-10deg of their respective trim values. However, high frequency oscillations are seen in the response of both phi and theta. In addition, similar high frequency oscillations are seen in the elevator deflection command. It is likely that the elevator servo was rate saturated during these oscillations.
2. Roll step: tracking performance is satisfactory. It is observed that the mean of phi tracks phi command to within+/-2deg. This deviation is within the steady-state error that was considered tolerable during the control synthesis. Although the mean tracks the command closely, high frequency oscillations are seen in phi and theta. These oscillations are also seen in the elevator deflection command and likely rate saturate the elevator servo.

Flight code

I. Aircraft: Baldr
II. Guidance: guidance/guidance_3n4.c (3 straight & level, 3 roll steps of +10deg, 3 rolls steps of -10deg, 3 pitch doublets of +/- 5deg)
III. Navigation: navigation/EKF_15state_quat.c
IV. Control: BALDR_OneSurfLeft_HINFDelayedCOLL /(autocoded C files)