Header

Date: 05/27/2015
Location: UMore Park Airfield
Aircraft: Baldr
Pilot: Danny Chryst
Flights: 1 Baldr
Purpose: Testing the LQG controller (with integrators) designed to use only the split elevators for stabilization & tracking.

Weather

- Clear with average wind speeds of 4mph (WSW). Max wind speed of 12mph. Visibility 9 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 271431Z AUTO 24003KT 10SM CLR 18/14 A2993 RMK AO2
KSGS 271434Z AUTO 22005KT 10SM CLR 19/14 A2993 RMK AO2 T01910144

Finish

KLVN 271530Z AUTO 26003KT 10SM CLR 21/14 A2993 RMK AO2
KSGS 271534Z AUTO 22007KT 10SM CLR 21/14 A2993 RMK AO2 T02130138

Introduction

Brian, Chris, Danny, and Raghu arrived at the UMore Park Airfield around 8:30am for the tenth flight of Baldr. In addition to Baldr flights, there were several Fenrir flights that are summarized in separate flight reports.

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 a linear quadratic Gaussian (LQG) controller, with the primary performance objective being output regulation. A secondary performance objective was tracking phi and theta commands. In order to track commands, two integrators were added to the synthesized LQG controller on the roll and pitch channels. The integrators effectively ensure that the steady-state tracking error is as close to zero as possible. In addition, the baseline controller runs for the first 2 seconds before the LQG controller is engaged. This simulates a realistic scenario wherein the flight control law has to switch from the baseline to the backup after a fault has been detected. The LQG 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 through 6) were used in this flight.

This experiment used ONLY the left elevator of Baldr to regulate outputs around trim and track phi and theta.

Experiment

A total of 12 runs were planned for this experiment. Only the first two runs were executed.

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 3 seconds after autopilot initiation and lasted a total of 30 seconds.	33
7,8,9	Roll step of -10deg about trim roll attitude of 0deg. Maneuver started 3 seconds after autopilot initiation and lasted a total of 30 seconds.	33
10,11,12	Pitch doublet of +/- 5 deg about trim pitch attitude of 5deg. Maneuver started 3 seconds after autopilot initiation and lasted a total of 6 seconds.	9

Observations

Only the first two runs, both straight and level, were executed. While the aircraft was airborne, the electric motor started producing a strange noise. For safety reasons, the flight was aborted and the aircraft was brought in for landing. Run number 1 was not very good, presumably because of a wind gust. The overall tracking performance in run number 2 was satisfactory. The controller does a good job in regulating phi and theta about their trim values. The tracking error in phi is in the range [-20, +15] deg and the tracking error in theta is in the range [-10, +20] deg. This is still considered good performance because of the inherent coupling between the longitudinal and lateral-directional motions from split elevator deflections.

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_LQG_LEFT/(autocoded C files)