Header

Date: 01/30/2015
Location: UMore Park Airfield
Aircraft: Baldr
Pilot: Danny Chryst
Flights: 1 Baldr
Purpose: Testing the modified loop-at-a-time controller designed to use only the split elevators for stabilization & tracking.

Weather

- Clear with average wind speeds of 5mph (S). Max wind speed of 12mph. 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 301641Z AUTO 18004KT 10SM CLR M09/M12 A3050 RMK AO2
KSGS 301630Z AUTO 12003KT 10SM CLR M08/M14 A3052 RMK AO2 T10851137

Finish

KLVN 301741Z AUTO 23005KT 10SM CLR M07/M11 A3046 RMK AO2
KSGS 301730Z AUTO 20007KT 140V220 10SM SCT120 M07/M13 A3049 RMK AO2 T10711127

Introduction

Brian, Chris, Danny, Parul, and Raghu arrived at the UMore Park Airfield around 8:30am for the fourth, fifth, and sixth flights of Baldr. In addition to Baldr flights, there was one Fenrir flight that took place. A separate flight report describes the purpose of the Fenrir flight.

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 implemented. Researchers decided to modify the baseline loop-at-a-time controller for this experiment. The baseline controller has two independently designed tracking loops. The pitch tracking loop generates an elevator deflection command in order to track a theta reference. The roll tracking loop generates an aileron deflection command in order to track a phi reference. It is important to note that each of the split elevators induce both longitudinal and lateral-directional motions in the aircraft. When both elevators deflect symmetrically, they act as elevators. When both elevators deflect anti-symmetrically, they act as ailerons. Hence, the pitch and roll tracking loops can be retained, with the only addition being a control command reallocation block. The reallocation involves mapping the conventional elevator and aileron commands into left and right elevator commands. Finally, 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.

Experiment

A total of 11 runs were planned for this experiment; only some of them were actually executed.

Executed runs: 1,2,3,4,5. The aircraft was unstable in the closed-loop and so the remaining runs were not executed.

Run #	Maneuver	Duration [s]
1,2,3	Trimmed in straight & level flight at 23m/s. Pitch = 5deg. Roll = 0deg. Throttle = 65%.	30
4,5,6,7,8	Roll doublet of +/- 10deg about trim roll attitude of 0deg. Maneuver started 3 seconds after autopilot initiation and lasted a total of 10 seconds.	13
9,10,11	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

It is observed that the aircraft is unstable when the loop is closed. Oscillations of increasing amplitude are seen in all states of the aircraft (phi, theta, psi, p, q, and r). The time-to-double for these oscillations is about one second. The oscillations are seen on all axes, i.e. pitch, roll, and yaw. Due to these unstable oscillations, the experiment was prematurely terminated. The pilot engaged the autopilot a total of five times and disengaged prematurely on all runs. Researchers believe that an extra proportional gain that was added for control reallocation may be to blame for these unstable oscillations. These unstable oscillations are not observable in either the linear or the nonlinear simulations of the UltraStick 120. This dataset can be used to investigate this phenomenon further. A useful task that can be performed using this dataset is the identification of a closed-loop linear model. Further, identifying a closed-loop pole location corresponding to the unstable oscillations can yield valuable insight into the dynamics of the UltraStick 120.

The flight data shows loss of sensor measurements from the pitot static system. Airspeed and barometric altitude readings freeze a few minutes into the flight. Pitot probe icing is considered to be the most likely cause of this anomaly.

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: control/baseline_control_two_surf.c