Different Control Methods for Adaptive Flight Control System

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1. Introduction

An Easy Fly System on a Bonanza Raytheon NASA Test-bed has been used by Wichita State University to develop a Neural Network Based Adaptive Flight Control System. This paper describes different control methods developed for the Easy Fly System in order to reduce the workload of the pilot while still giving him complete control of the aircraft. The simulation is done by interfacing X-PLANE, the flight simulation software, with MATLAB Simulink, wherein the controller models are constructed and compiled. The four different types of controllers that have been developed are i) flight path angle (γ) controller ii) pitch angle (θ) controller, iii) flight path angle rate (γ dot) controller and iv) pitch angle rate (θ dot) controller. In order to evaluate its stability and response, each controller requires the velocity and its corresponding parameter (for example, flight path angle for the flight path angle controller) to be commanded from the pilot. A trim feature has also been added for the controllers. These controllers have been designed for longitudinal control only, i.e. lateral control is not taken in to account while running the controller. Three of the four controllers have been evaluated for their performance and behavior by students of Wichita State University, who are pilots as well as non-pilots, the results of which will be presented.

2. Experiment and Results

Three out of the four different types of longitudinal flight controllers were tested and evaluated by students of Wichita State University. The evaluation was carried out by running the MATLAB version of the longitudinal controllers on one computer and interfacing it with another computer running a Bonanza simulation on X-PLANE, using User Datagram Protocol or UDP internet protocol. The three controllers that were evaluated were: i). Flight Path Angle (γ) Controller, ii) Flight Path Angle Rate (γ dot) Controller and iii) Pitch Angle (θ) Controller. X-PLANE simulated the cockpit instrument panel and a forward view from the aircraft. The evaluation pilots were seated at the computer running X-PLANE and were made to use a joystick with a power lever to control the aircraft. The MATLAB Simulink models displayed the numerical values of commanded speed and the corresponding input parameter depending on which controller was being evaluated. The commanded speed was also sent to X-PLANE and was displayed on the autopilot instrument panel. For the Flight Path Angle controller, a trim feature was added to set a desired rate of climb or descent. This rate was also displayed on the autopilot instrument panel. The students evaluated the system by performing the following flight test profile:

- Demonstrate speed control with stable speed at 90, 110 and 130 knots with near step input command changes as speed is changed.
- Demonstrate flight path control at several airspeeds:
    - Command level flight at 80 knots.
    - Climb to and level off at 4000 ft.
    - Speed up to 100 knots.
    - Descend back to 3000 ft resuming level flight.

- Command 120 knots.
- Climb back to 4000 ft and level off.
- Slow down to 80 knots.
- Descend back to 3000 ft.

The students evaluated the three controllers by performing the above flight test profile and by filling out a survey based on the Cooper-Harper scale [1]. The Cooper-Harper ratings and comments by the six students who participated in the evaluation have been summarized in the Tables 1-3.

Table 1:
Evaluation Summary for Flight Path Angle Controller

	Cooper-Harper Ratings by Student number	Student Comments
Flight Test Point		
1. Speed Control		“Holds velocity well” “Lost 60 ft of altitude while changing fro to 80 knots. Otherwise altitude held well”
2. Flight Path Control at various speeds		“Climbs and descends well within stalling limits” “Runs smoothl really slow at 80 knots” “Vertical speed fluctuates a lot a “Airspeed stayed right where I had set it while climbing and desc

Table 2:
Evaluation Summary for Flight Path Rate Angle Controller

	Cooper-Harper Ratings by Student number	Student Comments
Flight Test Point		
1. Speed Control		“Sensitive when reaching high/low speeds” “Seemed to start descend with changes in speed” “At higher speeds, it became i compensate for control”
2. Flight Path Control at various speeds		“Takes a while to get used to.” “Constant control is required” “ to maintain speed and climb as plane tends to crash” “Getting rates of climb was difficult at times” “Controller seemed to be tr zero rate of climb while climbing” “Major deficiencies!”

Table 3:
Evaluation Summary for Pitch Angle Controller

	Cooper-Harper Ratings by Student number						Student Comments
Flight Test Point	#1	#2	#3	#4	#5	#6	
1. Speed Control							“Constant force needs to be applied to the joystick in order altitude.” “Just a few ‘trim’ adjustments needed”
2. Flight Path Control at various speeds							“Less sensitive, requires more force over longer periods climb/descend.” “At a speed of 80 knots, it is nearly impossibl the altitude unlike at higher speeds.” “Speed is not mainta descent.” “Maximum rate of climb at 80 knots is 100 ft/min desirable.” “At airspeeds higher than 80 knots, it was easier to of the aircraft.” “Vertical speed climbs steadily and lowers suffic

3. Conclusions

From the tests and evaluations conducted, it was seen that Flight Path Angle Controller (γ) was the easiest to use when compared with the other two controllers. In addition, its performance, in terms of maintaining velocity and altitude, was also found to be better. The piloted flight simulations and flight test evaluations show that the controllers are proceeding toward acceptable handling qualities, but still need some work.

[1] Cooper-Harper Ref. NASA TND-5153