Six DOF Aircraft Simulator

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1 Introduction

The goal of this project is to implement a six degrees of freedom (DOF), nonlinear simulation for fixed-wing aircraft. The first iteration of this project is using a linear aircraft model. The second iteration will be using a nonlinear model.

2 Aircraft Model

The linear longitudinal and lateral models for a conventional fixed-wing aircraft could be written as follows [1].

$$\begin{bmatrix} \dot{u} \\ \dot{w} \\ \dot{q} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} X_u & X_w & 0 & -g\cos\theta_0 \\ Z_u & Z_w & u_0 & -g\sin\theta_0 \\ M_u & M_w & M_q & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} u \\ w \\ q \\ \theta \end{bmatrix} + \begin{bmatrix} X_{\delta_e} & X_{\delta_t} \\ Z_{\delta_e} & 0 \\ M_{\delta_e} & M_{\delta_t} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \delta_e \\ \delta_t \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} \dot{v} \\ \dot{p} \\ \dot{r} \\ \dot{\phi} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} Y_v & Y_p & -(u_0 - Y_r) & g\cos\theta_0 & 0 \\ \mathcal{L}_v & \mathcal{L}_p & \mathcal{L}_r & 0 & 0 \\ N_v & N_p & N_r & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & \sec\theta_0 & 0 & 0 \end{bmatrix} \begin{bmatrix} v \\ p \\ r \\ \phi \\ \psi \end{bmatrix} + \begin{bmatrix} 0 & Y_{\delta_r} \\ \mathcal{L}_{\delta_a} & \mathcal{L}_{\delta_r} \\ N_{\delta_a} & N_{\delta_r} \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \delta_a \\ \delta_r \end{bmatrix} \tag{2}$$

In this project we will consider the linear model of the aircraft "DELTA" given in [2, PP. 561–563] whose parameters are given as follows (at $U_0 = 75\ m/s$

and $\theta_0 = 2.7°$)

$$
\begin{aligned}
m &= 300000kg \\
X_u &= -0.02 \\
X_w &= 0.1 \\
Z_u &= -0.23 \\
Z_w &= -0.634 \\
M_u &= -2.55 * 10^{-5} \\
M_w &= -0.005 \\
M_q &= -0.61 \\
Y_v &= -0.078 \\
Y_p &= 0 \\
Y_r &= 0 \\
\mathcal{L}_v &= -0.086 \\
\mathcal{L}_p &= -1.0758 \\
\mathcal{L}_r &= 0.6334 \\
N_v &= 0.0037 \\
N_p &= -0.1121 \\
N_r &= -0.2569 \\
X_{\delta_e} &= 0.14 \\
Z_{\delta_e} &= -2.9 \\
M_{\delta_e} &= -0.64 \\
X_{\delta_t} &= 1.56 \\
M_{\delta_t} &= 0.0054 \\
Y_{\delta_r} &= 0.0065 \\
\mathcal{L}_{\delta_a} &= 0.46 \\
\mathcal{L}_{\delta_r} &= 0.1 \\
N_{\delta_a} &= 0.05 \\
N_{\delta_r} &= -0.21
\end{aligned} \tag{3}
$$

where δ_t is considered to be from the trim thrust. As such, δ_t is allowed the between 1 and -0.56 [3].

3 Algorithm Structure

4 Results

In this simulation example, the aircraft is subject to both elevator and aileron sinusoidal inputs with an amplitude of 5 degrees and a frequency of π rad/s.

Figures 1, 2 and 3 show the resulting translational velocities, rotational velocities and attitude angles, respectively.

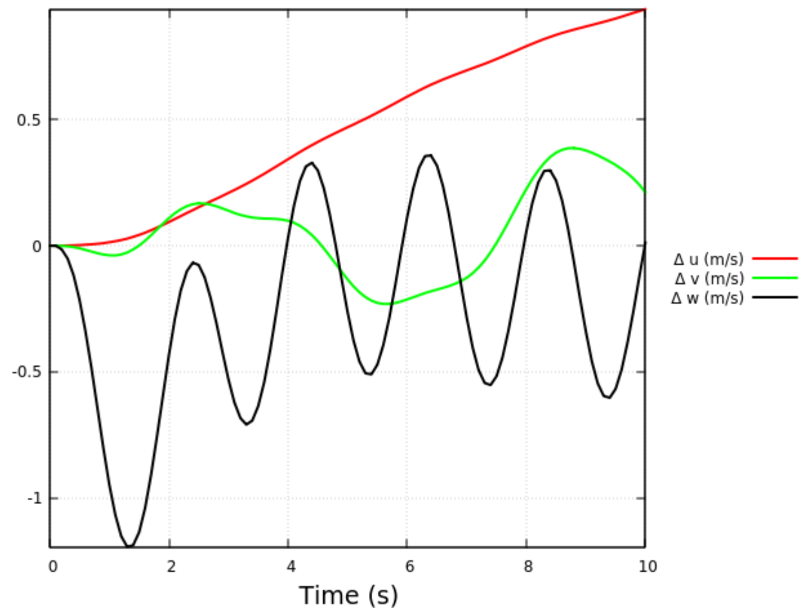

Figure 1: Translational velocities.

References

[1] Robert C Nelson. *Flight stability and automatic control.* McGraw-Hill, 2nd edition, 1998.

[2] D. McLean. *Automatic flight control systems.* Prentice Hall, 1990.

[3] Ahmed M Hassan and Haithem E Taha. Airplane loss of control problem: Linear controllability analysis. *Aerospace Science and Technology*, 55:264–271, 2016.

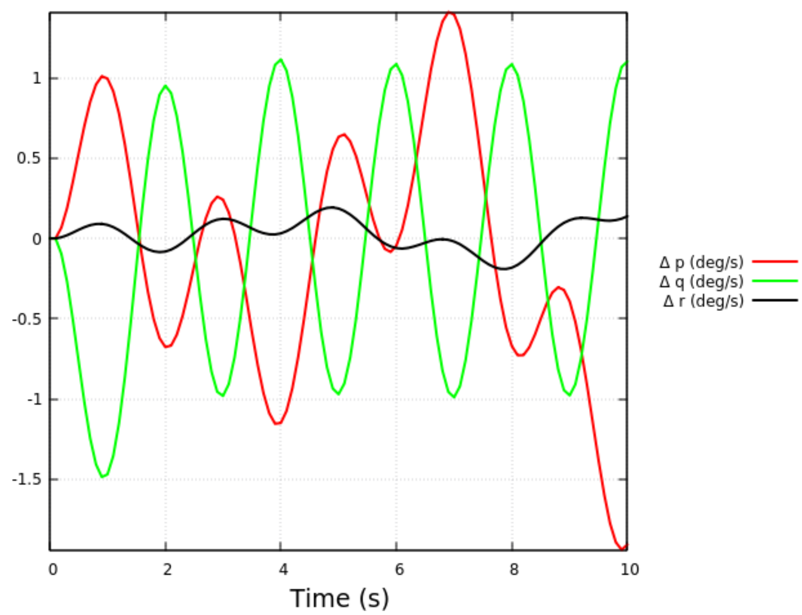

Figure 2: Rotational velocities.

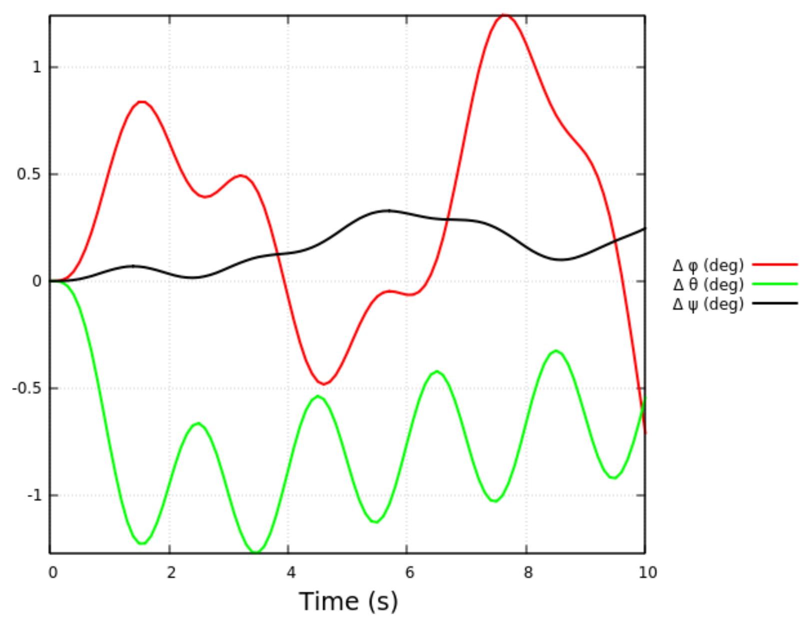

Figure 3: Attitude angles.