Numerical considerations relative to simulation of aileron-ruder controls in the roll-yaw motion

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Abstract
This paper deals with numerical considerations relative to simulation of aileron-ruder controls in the roll-yaw motion. The state of the art is analyzed in the first section, the initial system, in section two, the description of the process which obtains the steady state vector of the initial system, in section three, the linear system in section four and the conclusions, in section five.

1. State of the art
The simulation of an aerodyne with the aileron-ruder controls in roll-yaw motion has significance in the context of PIO [1]. In the literature of specialty this problem is studied in [2], [3] and [4].

2. The initial system
The system (1) is taken from [5]:
\[
\begin{align*}
\dot{\beta} &= y_\beta \beta + y_\delta_r \delta_r + y_\delta_a \delta_a + \frac{V_o}{g} \sin \phi \cos \theta_0 - r + p \alpha_0 \\
\dot{p} &= l_\beta \beta + l_p p + l_r r + l_\delta_r \delta_r + l_\delta_a \delta_a - i_1 r q_0 \\
\dot{r} &= n_\beta \beta + n_p (\beta) p + n_r (\beta) r + n_\delta_r \delta_r + n_\delta_a \delta_a + i_3 p q_0 \\
\dot{\phi} &= p + r \cos \phi g \theta_0
\end{align*}
\]

Where we have:
\[
\begin{align*}
\delta_r &= k_\beta \beta + k_r r \\
\delta_a &= k_p p + k_\phi \phi
\end{align*}
\]
with the following: \( k_\beta = -4.93 \), \( k_r = 7.67 \), \( k_p = 0.521 \), \( k_\phi = -0.28 \)

From [5] the following constants are used:
\( y_\beta = -0.195, \quad y_\delta_r = 0.045, \quad y_\delta_a = -0.03, \quad g = 9.81, \quad V_0 = 84.5, \quad l_\beta = -6.891, \quad l_p = -19.928, \quad l_\delta_r = 1.7, \quad l_\delta_a = 13.67, \quad r = 0, \quad n_\beta = 1.674, \quad n_\delta_r = -1.56, \quad n_\delta_a = 0.94 \)
The linearization of the system (1) is made in the point \((\beta_0, p_0, r_0, \phi_0)\) which is determined in the section three and expressed in the system (4). Also, the values of \((\alpha_0, q_0, \theta_0)\) are expressed in section three.

3. Obtaining the initial conditions

The initial conditions are obtained through an iterative process which contains four cycles; each cycle corresponds to one state of the system (1). The values of \((\alpha_0, q_0, \theta_0)\) are taken from [6] and are equal to \((0.189, 0, 0.12)\).

The numerical value of the point, in radians, is \((\beta_0, p_0, r_0, \phi_0) = (0.06782, -0.017266, 0.02273, 0.1178269)\).

4. The linear system

The system (4) is obtained by linearization of the system (1) in the point \((\beta_0, p_0, r_0, \phi_0)\) which is found in section three.

\[
\begin{align*}
\Delta \dot{\beta} &= y_{\beta} \Delta \beta + \alpha_0 \Delta p - \Delta r + \frac{g}{V_0} \cos \phi_0 \cos \theta_0 \Delta \phi + y_{\alpha} \Delta \delta_a + y_{\delta} \Delta r \\
\Delta \dot{\phi} &= l_{\beta} \Delta \beta + l_p \Delta p + (l_r - i_1 q_0) \Delta r + l_{\alpha} \Delta \delta_a + l_{\delta} \Delta \delta_a \\
\Delta \dot{\theta} &= n_{\beta} \Delta \beta + (a_3(2.865\alpha_0 + 0.3)\beta_0^2 + i_3 q_0) \Delta p + a_3(-0.005 - 1.07\beta_0^2) \Delta r + n_{\alpha} \Delta \delta_a + n_{\delta} \Delta \delta_a \\
\Delta \dot{\theta} &= \Delta p + \cos \phi_0 \tan \theta_0 \Delta r - r_0 \sin \phi_0 \tan \theta_0 \Delta \phi
\end{align*}
\]

Where \(i_1 = 0.9524\), \(l_r = 6.05\), \(a_3 = 18.45\)

![Fig. 1 The general representation of the system in simulink](image)

The input from Fig.1 is small and finite over time.
The outputs of the system (4) are:

\[ \beta \text{ vs. time} \]
Fig. 5  $p$ vs. time

Fig. 6  $r$ vs. time
5. Conclusions
Although the system (4) is instable, the automatic system makes the system stable. Following this idea this work is part of a much more complex study which involves automatic testing in time domain.

REFERENCES


