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]:

$$\begin{cases} \dot{\beta} = y_\beta \beta + y_{\delta_r}\delta_r + y_{\delta_a}\delta_a + \dfrac{g}{V_0}\sin\phi\cos\theta_0 - r + p\alpha_0 \\ \dot{p} = l_\beta \beta + l_p p + l_r r + l_{\delta_r}\delta_r + l_{\delta_a}\delta_a - i_1 r q_0 \\ \dot{r} = n_\beta \beta + n_p(\beta) p + n_r(\beta) r + n_{\delta_r}\delta_r + n_{\delta_a}\delta_a + i_3 p q_0 \\ \dot{\phi} = p + r\cos\phi tg\theta_0 \end{cases} \tag{1}$$

Where we have:

$$\delta_r = k_\beta \beta + k_r r \tag{2}$$

$$\delta_a = k_p p + k_\phi \phi \tag{3}$$

with the following: k_β = -4.93, k_r =7.67, k_p = 0.521, k_ϕ = -0.28

From [5] the following constants are used:
y_β =-0.195, y_{δ_r} =0.045, y_{δ_a} =-0.03, g =9.81, V_0 =84.5, l_β = -6.891, l_p =-19.928, l_{δ_r} = 1.7, l_{δ_a} = 13.67, $r = 0$, n_β =1.674, n_{δ_r} =-1.56, n_{δ_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.

$$\begin{cases} \Delta\dot{\beta} = y_\beta \Delta\beta + \alpha_0 \Delta p - \Delta r + \dfrac{g}{V_0}\cos\phi_0 \cos\theta_0 \Delta\phi + y_{\delta_a}\Delta\delta_a + y_{\delta_r}\Delta r \\ \Delta\dot{p} = l_\beta \Delta\beta + l_p \Delta p + (l_r - i_1 q_0)\Delta r + l_{\delta_r}\Delta\delta_r + l_{\delta_a}\Delta\delta_a \\ \Delta\dot{r} = n_\beta \Delta\beta + (a_3(2.865\alpha_0 + 0.3)\beta_0^2 + i_3 q_0)\Delta p + a_3(-0.005 - 1.07\beta_0^2)\Delta r + n_{\delta_a}\Delta\delta_a + n_{\delta_r}\Delta\delta_r \\ \Delta\dot{\phi} = \Delta p + \cos\phi_0 tg\theta_0 \Delta r - r_0 \sin\phi_0 tg\theta_0 \Delta\phi \end{cases} \tag{4}$$

Where i_1 =0.9524, l_r =6.05, a_3 =18.45

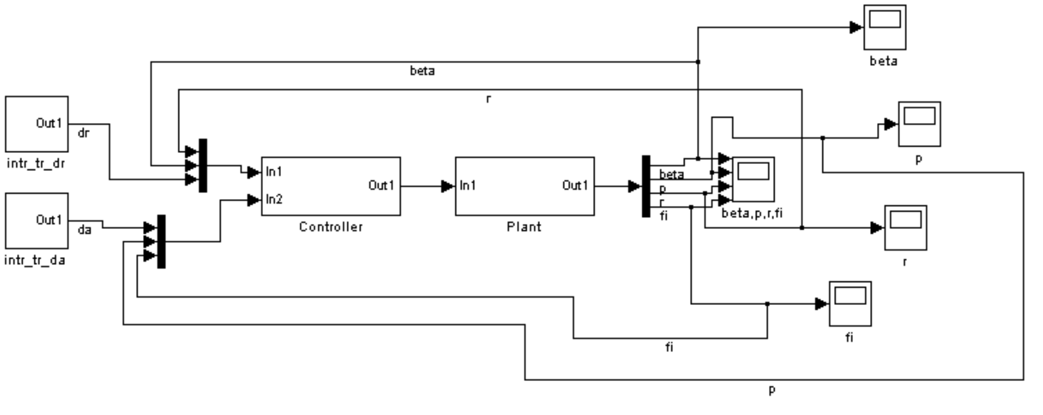

Fig. 1 The general representation of the system in simulink

The input from Fig.1 is small and finite over time.

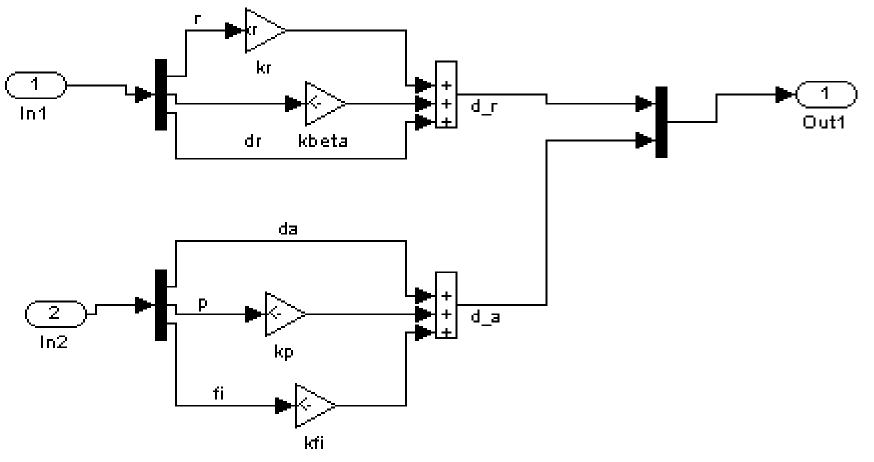

Fig. 2 The controller subsystem

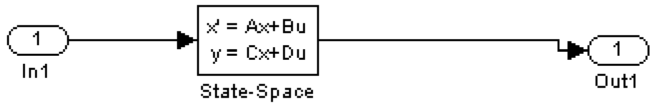

Fig. 3 The plant subsystem

The outputs of the system (4) are:

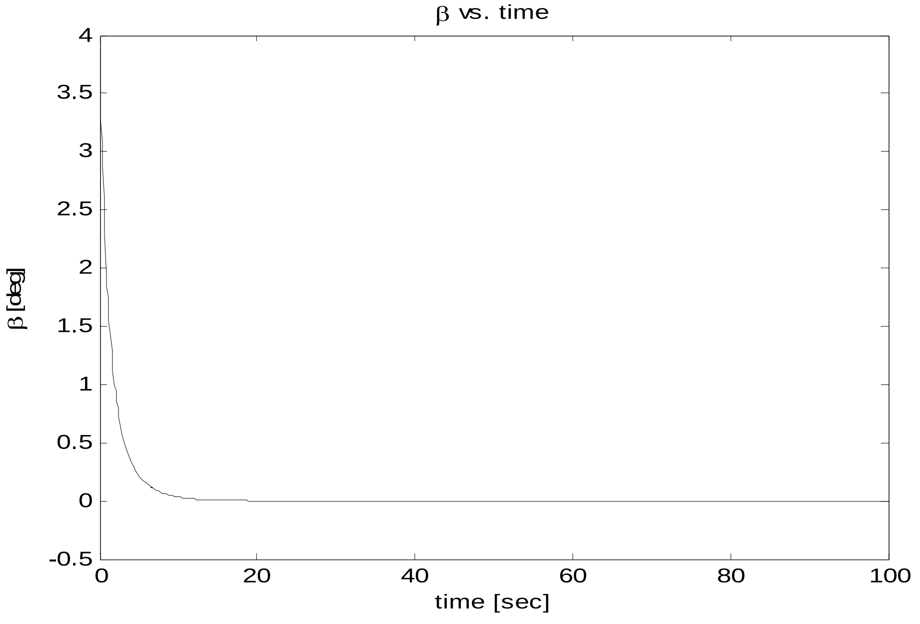

Fig. 4 β vs. time

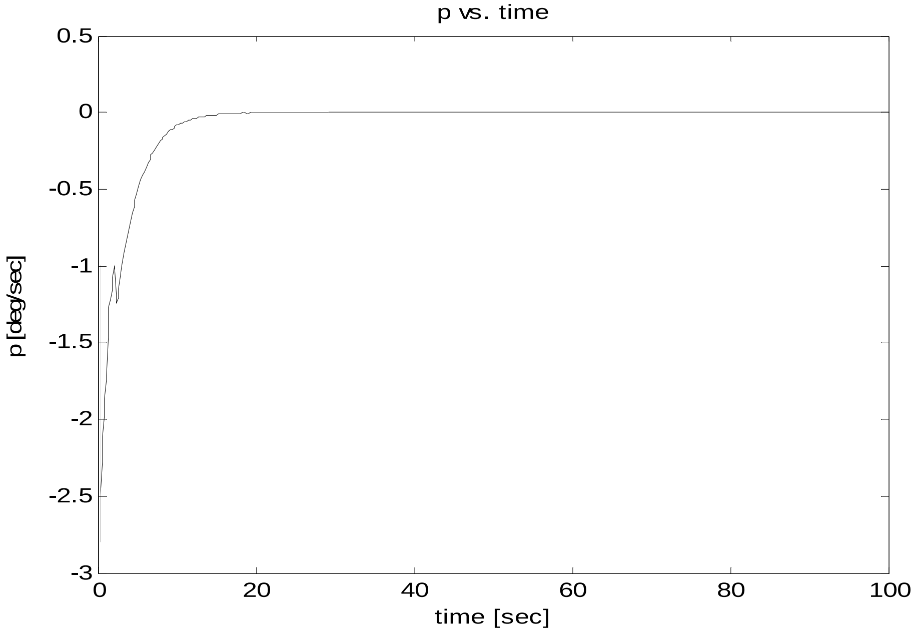

Fig. 5 p vs. time

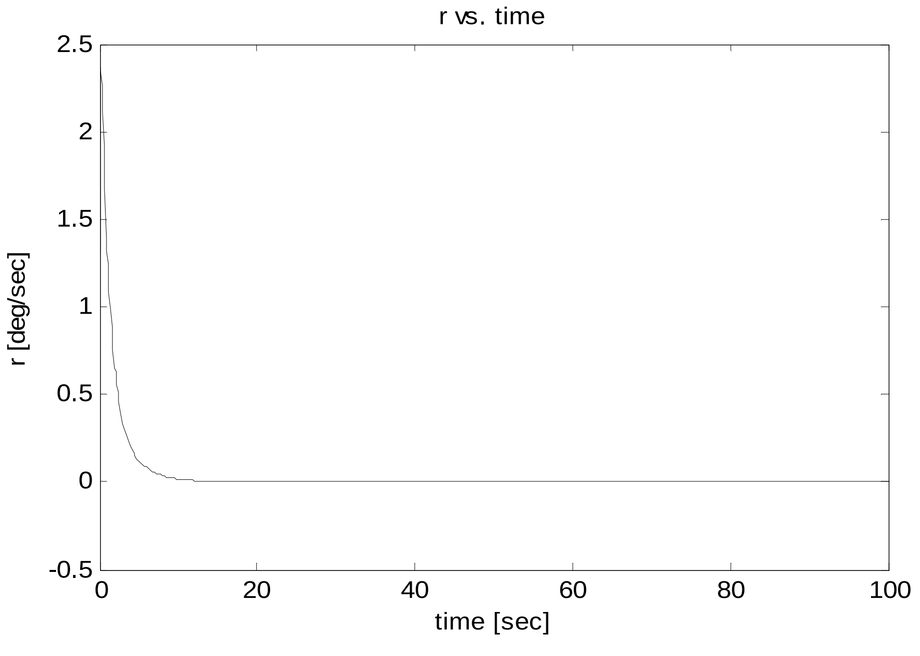

Fig. 6 r vs. time

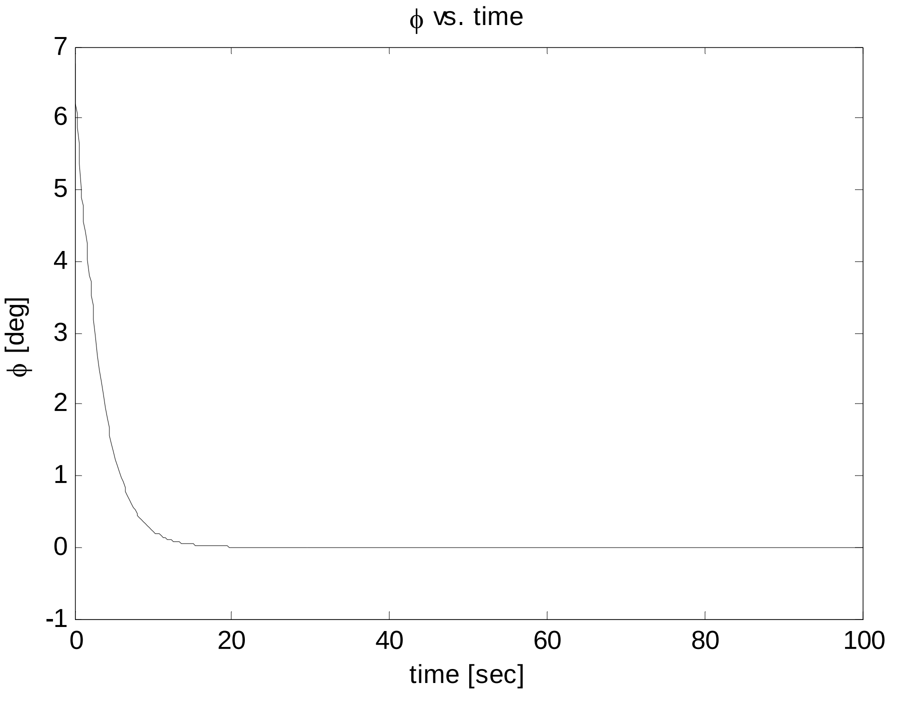

Fig. 7 ϕ vs. time

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.

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