SYS-6581 Principles of Modeling for Cyber-Physical Systems

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1 State-space modeling in MATLAB

1.1 Simplified Car Dynamics

(a) Dynamic equation of the system in state space representation:

$$\begin{bmatrix}\dot{x}_1\end{bmatrix} = \begin{bmatrix}-bx_1/m\end{bmatrix}\begin{bmatrix}x_1\end{bmatrix} + \begin{bmatrix}1/m\end{bmatrix}u$$

$$y = v = x_1$$

(b) Only one state is needed.

(c) System is linear in the state.

(d) The system is time invariant.

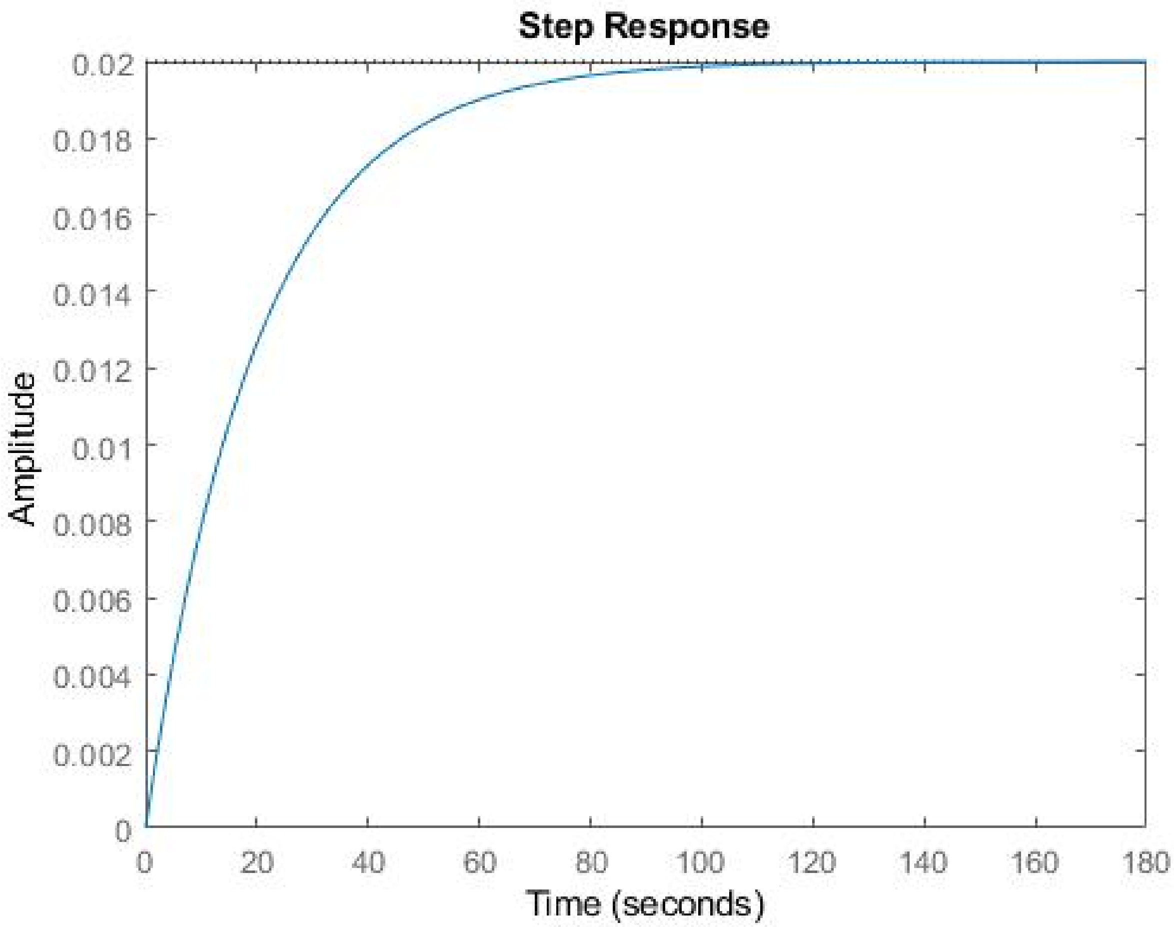
(e) x_2 is equal to v, or velocity.

(f) The dimension for A, B, C, D are all 1 x 1.

(g) I attached cruise.m.

(h) "ss" is in continuous time.

(i) Here is the plot:



(j) One can infer the order of the system from the step response; there seems to be a particular signature for each.

1.2 Aircraft pitch autopilot

(a) Here is the dynamical equation of the system in state space representation

$$\begin{bmatrix} \dot{\alpha} \\ \dot{q} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} -0.313 & 56.7 & 0.232 \\ -0.0139 & -0.426 & 0.0203 \\ 0 & 56.7 & 0 \end{bmatrix} \begin{bmatrix} \alpha \\ q \\ \theta \end{bmatrix} + \begin{bmatrix} 0.232 \\ 0.0203 \\ 0 \end{bmatrix} \delta$$

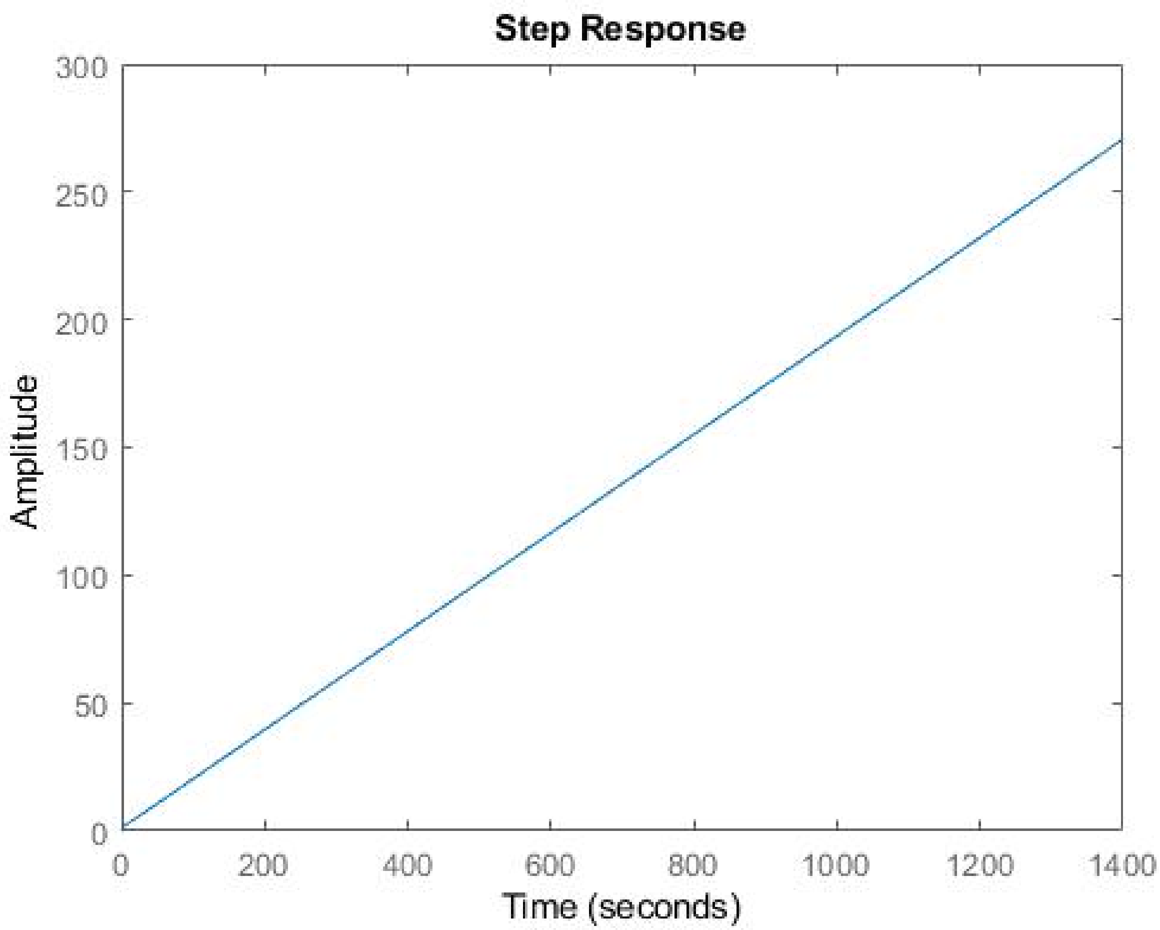
$$y = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha \\ q \\ \theta \end{bmatrix}$$

(b) Three states are needed.

(c) A is 3 x 3, B is 3 x 1, C is 1 x 3, and D is a 1 x 1 zero matrix.

(d) Attached aircraft.m.

(e) Here is the plot:



The physical interpretation indicates that changing the deflection angle δ has a linear relationship with the pitch angle θ of the aircraft.