EE 433 Nonlinear and Adaptive Control

Adaptive Control Project II

Adaptive Control of an Aircraft's Pitch Dynamics

Consider the following nonlinear pitch dynamics

$$\begin{aligned}\dot{\alpha} &= q + a_1\alpha + a_2\alpha^2 + a_3 u \\ \dot{q} &= m_0 + m_1\alpha + m_2\alpha^2 + m_\delta(\alpha)u\end{aligned} \qquad (1)$$

where α is angle-of-attack in radians, q is the pitch rate in rad/s, u is the elevon surface deflection in radians, and $m_\delta(\alpha)$ is the nonlinear elevon effectiveness given by $m_\delta(\alpha) = m_4 + m_5 \exp(m_6\alpha)$. Data for the model in Eq. (1) is:

$a_1 = -5.79$	$m_0 = 0.02$	$m_4 = -0.4$
$a_2 = -0.65$	$m_1 = 0.57$	$m_5 = -0.2$
$a_3 = -1.15$	$m_2 = 0.20$	$m_6 = -9.0$

1. Design a baseline controller for the system described in Eq. (1) to track constant AOA commands using the nominal parameter values listed above. The baseline controller can be a linear/classical design, a gain scheduled design, or a nonlinear approach. Simulate the design tracking an AOA command sequence of 0, 5, 0, 12, 0 degrees.

2. Design an adaptive increment to the baseline controller derived and implemented in 1) to make the system robust to uncertainties in the coefficients and unmeasurable disturbance $d(x,t)$ described by (this is Eq. (1) rewritten to include the disturbance)

$$\begin{aligned}\dot{x}_1 &= f_1(x) + g_1(x)u \\ \dot{x}_2 &= f_2(x) + g_2(x)u + d(x)\end{aligned}$$

where

$$f_1(x) = q + a_1\alpha + a_2\alpha^2$$
$$f_2(x) = m_0 + m_1\alpha + m_2\alpha^2$$
$$g_1(x) = a_3$$
$$g_2(x) = m_\delta(\alpha)$$
$$d(x) = -m_1(\alpha - 8 * dtr)\left(0.1\left(q - 0.65\alpha^2\right)\right)$$

$a_1 = -5.79$	$m_0 = 0.02 \pm 0.04$	$m_4 = -0.4 \pm 0.10$
$a_2 = -0.65$	$m_1 = 0.57$	$m_5 = -0.2$
$a_3 = -1.15$	$m_2 = 0.20 \pm 0.12$	$m_6 = -9.0 \pm 3.0$

and where dtr is a conversion from degrees to radians.

Demonstrate in numerical simulation the robustness of the system using the baseline control augmented with the adaptive increment.