Adaptive Control Systems
Nonlinear Adaptive Control project
ME 6574/ECE 6774/AOE 6774

The purpose of this project is to design a model reference adaptive controller for a DC motor drive, which accounts for the presence of an unknown deadzone in the power electronics, so that approximate velocity tracking may be achieved without knowledge of motor, load, or deadzone parameters.

The dynamics of a brush-commutated permanent-magnet DC motor turning an inertial load are described by

$$
\begin{aligned}
J\frac{d\omega}{dt} &= -B\omega(t) + Ki(t) \\
L\frac{di}{dt} &= -K\omega(t) - Ri(t) + v(t)
\end{aligned}
$$

where $\omega(t)$ is the mechanical state variable (angular velocity), $i(t)$ is the electrical state variable (armature current), and $v(t)$ is the input to the motor terminals (armature voltage). The constant but unknown mechanical parameters are inertia J and viscous friction B, and the constant but unknown electrical parameters are armature inductance L, armature resistance R, and motor constant K. Even if the electrical parameters are presumed to be known, all of the coefficients of the plant transfer function will be unknown. Each of the unknown parameters, i.e. J, B, L, R, K, are known to be strictly positive.

The voltage input $v(t)$ to the motor is not directly controlled, but instead is the output of a power electronic circuit which may be modeled as a deadzone

$$
v(t) = \begin{cases} m(u(t) - b_r) & , \ u(t) \geq b_r \\ 0 & , \ b_l < u(t) < b_r \\ m(u(t) - b_l) & , \ u(t) \leq b_l \end{cases}
$$

The objective is to find a reference input $u(t)$, in terms of the desired voltage input $v_d(t)$, by attempting to cancel the effects of the deadzone. An adaptive estimate of the deadzone inverse is given by

$$
u(t) = \begin{cases} \frac{v_d(t) + \widehat{mb_r}(t)}{\hat{m}(t)} & , \ v_d(t) \geq 0 \\ \frac{v_d(t) + \widehat{mb_l}(t)}{\hat{m}(t)} & , \ v_d(t) < 0 \end{cases}
$$

The signal $v_d(t)$ is designed such that, if $v(t) = v_d(t)$, the output velocity $\omega(t)$ tracks a desired velocity signal $\omega^d(t)$ provided as the output of a reference model. The only measurement of the plant response available to the control system is the output $\omega(t)$ (i.e. $i(t)$ and $v(t)$ are not available). The desired output is specified to be

$$
\omega^d(t) = 10\sin(2t)
$$

but the choice of reference model (and corresponding reference signal $r(t)$) is not specified.

For purposes of plant simulation, the true values of the unknown motor and load parameters are

$$J = 0.0026 \quad B = 0.00057 \quad L = 0.0045 \quad R = 0.5 \quad K = 0.56$$

whereas the true values of the unknown deadzone parameters are

$$m = 2 \quad b_r = 0.8 \quad b_l = -1.2$$

Implementation of the adaptive deadzone inverse should make use of projection to insure that, for all time $t \geq 0$, known parameter bounds are not violated, i.e.

$$0.2 \leq \widehat{m}(t) \leq 5 \quad 0 \leq \widehat{b}_r(t) \leq 10 \quad -10 \leq \widehat{b}_l(t) \leq 0$$

Write software that implements the plant dynamics, the reference model dynamics, the deadzone and estimated deadzone inverse, the filter dynamics (if necessary), and the adaptation dynamics, for the four cases described below. Demonstrate the operation of each case; at minimum, plot (1) the actual plant output ω along with the reference model output ω^d, and (2) the adjustable controller parameters along with their unknown perfectly tuned constant values, as functions of time, to determine how well, if at all, the output tracking objective is met (and to what extent parameter convergence is achieved).

1. First-order plant model ($L = 0$), required part
   (a) Unknown deadzone, known motor/load.
   (b) Unknown deadzone, unknown motor/load.
2. Second-order plant model ($L > 0$), for extra credit
   (a) Unknown deadzone, known motor/load.
   (b) Unknown deadzone, unknown motor/load.