Intelligent control of a single-link flexible manipulator using sliding modes and artificial neural networks

This algorithm represents the implementation of a new intelligent control scheme for the accurate trajectory tracking of flexible link manipulators. The proposed approach is mainly based on a sliding mode controller for underactuated systems with an embedded artificial neural network to deal with modeling inaccuracies. Online learning, rather than supervised offline training, is adopted to allow the weights of the neural network to be adjusted in real time during the tracking.

Algorithm: Sliding Mode Control and Artificial Neural Networks for underactuated systems.

Define control parameters
Appraise initial states
loop
  Evaluate desired trajectory
  Compute tracking error
  $s_r \leftarrow -\alpha_a\ddot{\theta}_d + 2\lambda_a\dot{\tilde{\theta}} + \lambda_a^2\tilde{\theta} - \alpha_u\ddot{\phi}_d + 2\lambda_u\dot{\tilde{\phi}} + \lambda_u^2\tilde{\phi}$
  $s \leftarrow \alpha_a\ddot{\theta} + \alpha_u\ddot{\phi} + s_r$
  $\boldsymbol{w}_i \leftarrow \boldsymbol{w}_{i-1} + \nu s_i \boldsymbol{\psi}(s_i)\Delta t$
  $\hat{d} \leftarrow \boldsymbol{w}^\top \boldsymbol{\psi}(s)$
  $u \leftarrow -M_s^{-1}[f_s + \hat{d} + \dot{s}_r + \kappa\,\mathrm{sat}(s/\varphi)]$
  Apply u to the system
  Update states: $\theta,\ \phi$
  Filter the states' signals
  Estimate the states' time derivatives
end loop

Adopted parameters:

- Sliding modes

$\hat{M}_s = 12.5;$	$\hat{f}_s = 0;$	$\kappa = 20;$	$\varphi = 0.25;$
$\alpha_a = 0.017;$	$\alpha_u = 0.017;$	$\lambda_a = 1.3;$	$\lambda_u = 1.3.$

- Neural network
  - Seven neurons with Gaussian activation functions are adopted in a single hidden layer: $\psi_i(s;\mu_i,\sigma_i) = \exp\{-0.5[(s-\mu_i)/\sigma_i]^2\}$;
  - The weight vector is initialized as $\boldsymbol{w} = \mathbf{0}$ and updated according to $\dot{\boldsymbol{w}} = \nu\, s\, \boldsymbol{\psi}$.

with

$$\nu = 1.8;$$
$$\boldsymbol{\mu} = [-1.2\varphi,\ -\varphi/1.5,\ -\varphi/3,\ 0,\ \varphi/3,\ \varphi/1.5,\ 1.2\varphi];$$
$$\boldsymbol{\sigma} = [\varphi/2,\ \varphi/2,\ \varphi/4,\ \varphi/4,\ \varphi/4,\ \varphi/2,\ \varphi/2].$$