Aerospace Engineering | Dec Making
Seoul National University | Spring '24

HW 2 (due June 3 at etl.snu.ac.kr)

1. This problem is based on the Matlab example "Sliding Mode Control Design for a Robotic Manipulator" available at the following site :
https://www.mathworks.com/help/slcontrol/ug/design-smc-controller-for-robotic-manipulator.html

   We would like to design a sliding mode controller (SMC) for a robotic manipulator with two actuated joints, whose dynamics is
$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + G(q) + F(\dot{q}) = \tau + \tau_d$$
   where

   - $q, \dot{q}, \ddot{q}$ are 2-by-1 vectors representing the joint angles, velocities, and accelerations, respectively.
   - The control input τ is 2-by-1 torque vector applied to the joints.
   - The inertia matrix $M(q)$, Coriolis matrix $C(q,\dot{q})$, gravity vector $G(q)$, and friction vector $F(\dot{q})$ encapsulate the dynamics of the manipulator
   - τ_d represents the disturbance torques affecting the system, and the magnitude of its elements is upper-bounded by $D = [10, 5]^T$.

   (a) Given a desired trajectory q_d, design SMC so that $q - q_d \to 0$.
   (b) Perform simulation with your choice of q_d and τ_d, and observe the difference using "sign" function vs saturation function.

2. Design a nonlinear model predictive controller for the manipulator in No. 1. See if there is a difference between when $\tau_d = 0$ and $\tau_D \neq 0$. You may refer to the Matlab example "Control Robot Manipulator Using Passivity-Based Nonlinear MPC" at the following site :
https://www.mathworks.com/help/mpc/ug/control-of-robot-manipulator-using-passivity-based-nonlinear-mpc.html

3. Design a backstepping control for the following system:
$$\begin{aligned}\dot{x} &= ax - x^3 + \xi \\ \dot{\xi} &= u\end{aligned}$$
   (a) Let $a = 1$, and design a backstepping control such that $x(t) \to x_d(t)$.
   (b) Let a be an unknown constant, and design an adaptive backstepping control such that $x(t) \to x_d(t)$.
   (c) Simulate (b) with your choice of x_d, and check the state/parameter convergence.

4. Consider the nonlinear system:
$$\begin{aligned}\dot{x}_1 &= x_1 + x_1x_2 - x_2^2 + u \\ \dot{x}_2 &= x_1x_2 - x_2^2 + u \\ \dot{x}_3 &= x_1 + x_1x_2 - x_2^2 - (x_3 - x_1)^3 + u \\ y &= x_1 - x_2\end{aligned}$$
   (a) Show that the system has relative degree two.
   (b) Define the internal variable, and transform the system into the normal form.
   (c) Show that the origin of the zero dynamics is globally asymtotically stable.
   (d) Design a feedback law that achieves global asymptotic stability.

5. (Term project proposal) The course project may be:
A. an independent research project that can utilize any of the techniques covered in the course, or
B. a review of the literature in an area covered in or related to the course.
You may choose a project related to your area of research, and/or you may choose to apply any of the techniques from class to a system that you are interested in.

   - In the case of an independent research project, you should submit a paper which summarizes related work, describes your problem and method, and presents your results.

- In the case of a literature review, you should submit a report which provides the background review, presents a clear description of the results presented in the papers that you are reviewing, and gives your own assessment of these results.
- The projects will be evaluated according to correctness and depth of your analysis or review, and your written presentation.
- Please prepare to give a brief (< 3 min) proposal presentation on June 5, describing your topic and what you plan to accomplish in your project.
- The final course project papers or reports are due **11:59 pm, June 17**. Recommended length: 6–12 single-column pages, or 3–6 double-column pages.