Modeling and control of cyber-physical systems (CPSs)
Project Part II: distributed control of a multi-agents magnetic levitation system

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May 2023

System description

- The system under study is a CPS made up of 7 magnetic levitation (maglev) systems as the one shown in figure:

CPS mathematical modeling

The CPS under study has to be modeled as a multi-agents system where:

- one maglev system acts as *leader node* S_0
- the other 6 maglev systems act as *follower nodes* S_i $(i = 1, 2, \ldots, N)$
- Each single agent is described by the following state-space equations obtained by linearizing the physical equation around a suitable equilibrium point

$$\dot{x}_i = Ax_i + Bu_i, \; y_i = Cx_i \tag{1}$$

where:

$$A = \begin{bmatrix} 0 & 1 \\ 880.87 & 0 \end{bmatrix}, \; B = \begin{bmatrix} 0 \\ -9.9453 \end{bmatrix}, \; C = [708.27 \; 0], \; D = [0] \tag{2}$$

- State variables are not directly accessible for measurement

Project description

General task description and network structure selection

- In this project activity, the students (organized in groups of 3/4) are required to design a distributed control protocol such that the multi-agents system perform the cooperative tracking problems (i.e. the global disagreement error is driven asymptotically to 0).

- Each group can freely choose the structure of the communication network used by the agents to share information. The students are invited to:
  - consider different network structures
  - provide a discussion on the effect of the network structure on the controlled system behavior
  - select a particular structure and motivate their choice

Project description

Control protocol

As far as the control protocol is concerned the students are invited to:

- design a distributed regulator based on a distributed *neighborhood* observer structure
- design a distributed regulator based on local observers
- provide a discussion about the numerical comparison of the two different approaches when the following scenarios are considered :
  - the leader agent steady-state reference behavior is constant (amplitude R_0 to be freely selected)
  - the leader agent steady-state reference behavior is a ramp (slope R_0 to be freely behavior)
  - the leader agent steady-state reference behavior is a sinusoidal signal (amplitude A and frequency ω_0 to be freely chosen)
- More specifically, the students are invited to numerically analyze:
  - The effect of possible noise affecting the output measurements.
  - The effect of the selected values for the coupling gain c and the weighting matrix (Q and R) used for designing the controller and the observer.