ENGR 580: Project handout #4 Observability and output feedback

November 2023

Use the models and state-feedback control structures you defined in part A and part B of your project following the instructions of handout 1, 2 and 3.

1 Part A: Irrigation system sample project

Given the model you defined for the multiple sprinkler system using the interconnected compartmental model:
1.1 Given the model you developed based on handout 2 (only the run-off is measured), is this system observable?
1.2 What is the minimal number of sensors required to make the multi-sprinkler system observable?
1.3 Calculate a Kalman decomposition for this system and indicate any unobservable and uncontrollable parts.

2 Part B: Design project

2.1 Is the system you chose in your project observable?
2.2 *If your system is not observable*: Calculate the Kalman decomposition. Is your system detectable? Which sensors could you add to make your system observable? Would that be realistic?
2.3 *If your system is observable*: If you have more than one output: Is your system still observable in the case of sensor failure (for any of your sensors)? If your system is no longer observable, calculate a Kalman decomposition. Is this system detectable? If you have only one output: Is there a C (matrix) that would make your system unobservable? If so, calculate the Kalman decomposition for this system. Is this system detectable? What type of sensor would this C matrix represent, if any at all?

If your system has the same number of outputs as states, you will need to adjust your measurements for the remainder of this project. Following the discussion above, choose a reasonable sensor configuration for which your system has less outputs than states, yet remains observable.

2.4 Assume that your system is configured with the sensors required to make it observable and that the number of outputs is strictly smaller than the number of states $m < n$. Design an observer for your system. In simulation, evaluate how well your observer tracks the states of the linear system, and of the nonlinear system.
2.5 Use an observer to design and implement an output feedback controller for your system with the configuration indicated in the previous question. Simulate a homogenous response with a realistic x_0.
2.6 Configure your control system such that it can track a reference. Configure your control system to track a reference using output feedback. Simulate the response to a step or other realistic reference signal for both your linearized system and your nonlinear system. Does the controller meet your specifications?
2.7 Evaluate your reference tracking design in the presence of realistic measurement noise in each of your output channels. Does your controller design meet your specifications for your nonlinear system? If not, how could you change your design to improve the performance?