TTK4210 Advanced Control of Industrial Processes
Department of Engineering Cybernetics
Norwegian University of Science and Technology
Spring 2018 - Assignment 7
Due date: Friday 23 March at 16:00

Consider the process

$$y(s) = \frac{2.5(-10s+1)e^{-2s}}{(100s+1)(10s+1)}u(s) + \frac{1.5}{(100s+1)}d(s)$$

where

- y is a measurement which should be controlled,
- u is the input, and
- d is a disturbance

You have the following constraints:

$$-2.0 < y < 2.0$$
$$-1.0 < u < 1.0$$

1. **Controller design**

   Design an MPC controller, and choose

   - which model representation to use (state-space, step response, ...), and
   - all relevant tuning parameters.

   Note that in this assignment you will have to make your own MPC, i.e. **not** use the Matlab MPC Toolbox.

   (**Hint:** MPC is described in the Lecture notes, Chapter 5.)

   Use an MPC formulation with no stationary deviation (both when the disturbance is measured and when it is not). This will require you to introduce *input changes* as a free variable in the optimization, and to *extend the state vector* with the input variables to make it possible to implement the input constraints.

   If you use a state-space model, you may assume that all states are known (measured) - provided that a minimal realization is used for the model. This is actually an unrealistic assumption, especially if the process has a zero in the right-half plane, but the assumption is anyway used here to be able to avoid use of state estimators in this assignment. To make the control problem approximately equally hard as when updating directly from a measurement (as for a step response formulation), it is supposed that the weight matrix for the states in the optimalization criterion is chosen to be of the form

   $$Q = C^T \widehat{Q} C$$

where $\widehat{Q}$ is the weight on the (scalar) measurement, and C is the measurement matrix in the state-space model.

For generation of *state references*, have a look at the Section *Target calculation* in the Lecture Notes.

If you use a step response model, you will have to assume that only the measurement of the controlled variable (and possibly the disturbance) is accessible.

2. **Simulation**

   Simulate the response for the system in the following cases:

   (a) A reference step from $y_r = 0$ to $y_r = 1$, assume that this is not known in advance.

   (b) As in (a), but assume that the reference step is known in advance.
   (**Hint:** A stepwise reference change is dynamically similar to a stepwise measurement disturbance.)

   (c) A step in the disturbance from $d = 0$ to $d = -1$, with constant referance $y_r = 0$. Assume that the disturbance is not measured or known in advance.

   (d) As in (c), but assume that the disturbance is measured (i.e. a forward-connection from a measured disturbance), but not in other ways known in advance.

Try to make rapid control, and to minimize the size of the optimization problem. This is not necessarily desirable in general, but it can illustrate differences between the MPC formulations.

The assignment should be documented in a short report, where you explain what MPC formulation is used, including how the model is updated from the measurement(s), and which values are chosen for the tuning parameters. Two students can cooperate and hand in a common report.

Note: As usual when reporting your results, you have to plot the output together with the reference, to make it possible to assess the performance of the controller.
It is also preferable if you can give some kind of quantitative results.