Exercise 5 BottomUp and Interaction

1. Explain why the standard Smith predictor does not work for processes with integration or unstable dynamics.

2. Smith's controller for a process $P(s) = P_0(s)e^{-sL}$ with time delay is given by

$$C(s) = C_0(s)C_{pred}(s), \qquad C_{pred}(s) = \frac{1}{1 + P_0(s)C_0(s)(1 - e^{-sL})}$$

where C_0 is the nominal controller for the process P_0 without delay and L is the time delay. The transfer function $C_{pred}(s)$ is actually a good predictor that also can be used for loop shaping.

a. Explore the Bode plot of the predictor $C_{pred}(s)$ for

$$P_0(s) = \frac{1}{s+1}, \qquad C_0(s) = 2 + \frac{4}{s}.$$

Demostrate that $C_{pred}(s)$ is indeed a good phase lead compensator.

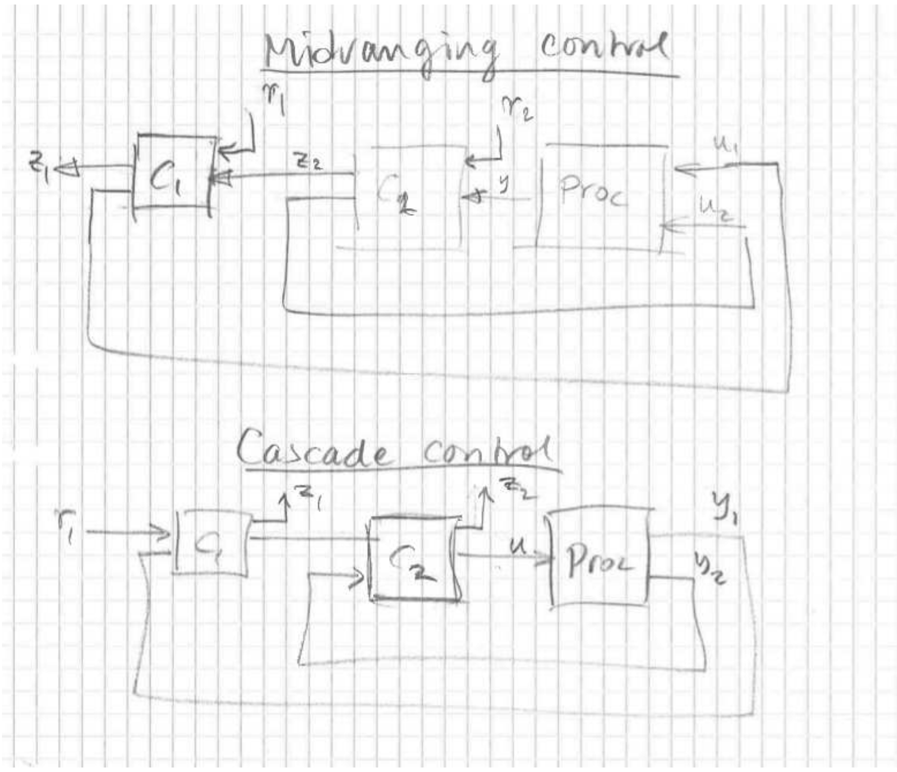
b. The properties of the compensator $C_{pred}(s)$ changes qualitatively with L, explain the nature of the changes and find the smallest value of L for which the change occurs.

c. Use the insight from c) to discuss fundamental limitations of the Smith predictor C_{pred}.

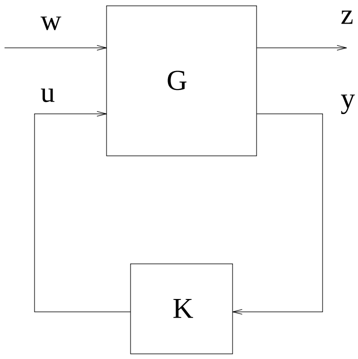
d. Smith's predictor can be used as a lead compensator without reference to time delays. Explore if it can be used as a lead compensator for the oscillatory system $P(s) = \dfrac{1}{s^2 + 0.02s + 1}$ which we studied in a previuos exercise.

3. The robot lab has a rack and pinion actuator with motors that act on the pinion. It is desirable that the motors should cooperate for large fast motions but they should counteract for small motions to avoid backlash. Propose a controller structure with PID control and discuss how integral action should be introduced and how windup protection could be done.

4. This exercise illustrates that one can consider midrange control to be the dual of cascade control. Consider the description in the attached figure of the two problems. The signals z_i can be considered as supervisory signals delivered by the controllers.



a. Find $G_{11}, G_{12}, G_{21}, G_{22}$ for the two design problems in the form described below. The controller block K will have a block diagonal structure.



b. Show that $G_{midranging} = G^T_{cascade}$ and $K_{midranging} = K^T_{cascade}$ if C_1, C_2 and the process block for the midranging problem are the transposes of the corresponding blocks for the cascade control problem. The system is illustrated in figure 4.3 page 36 in Patrik Cairen's master thesis, see the Publication data base.

5. There is a multivariable version of the Nyquist criterion: Consider a MIMO system with loop gain matrix $G_0(s)$ of size $N \times N$. The closed loop system with negative unit feedback $u = -y$ will be stable if the N curves defined by the eigenvalues of G,

$$\omega \mapsto \lambda_i(G(i\omega)), \qquad i = 1, \ldots, N$$

encircle the point -1 in total P_u times counter-clockwise, where P_u is the number of unstable poles to $G_0(s)$.

Find a 2 by 2 example $G_0(s)$ so that these two Nyquist curves show excellent margins to the point -1 but the system is anyway quite nonrobust, in the sense that a small perturbation to $G_0(s)$ can destabilize the closed loop. (Hint: Use a triangular G_0)