Control System Analysis Exam

Evidence-based Control Engineering Education:
Evaluating the LCSD Simulation Tool

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Abstract

This document presents the exam on control system analysis that 101 students performed at the *Pontifical Catholic University of Valparaiso* (Chile) in 2019-20. Although students were separated into two groups to perform lab practices with LCSD and Matlab CST, they all undertook the exam in this document. It is worth remarking that, in the Chilean education system, students are graded from 1 to 7.

In the question items, we have highlighted in blue the following fine-grained indicators: TR (Transient Response of a control system), SS (Steady State), RL (Root Locus), BD (Bode diagram), and ND (Nyquist diagram). The notation *INDICATOR*-I and -C distinguishes between the scores that students obtained interpreting and calculating the indicator, respectively. For instance, TR-I stands for the students' scores on the interpretation of TR, and TR-C stands for the students' scores on TR calculation.

1 Question 1 *(4 points)*

Examine the following closed-loop control system:

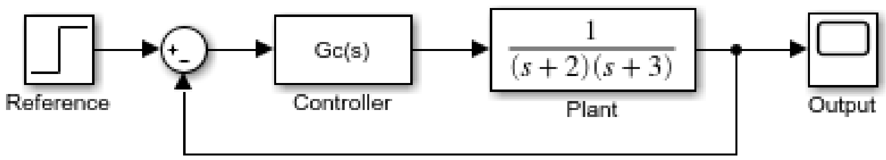


Figure 1: Control system to be analyzed.

Case 1: Considering that the controller is $G_c(s) = K$:

a) Compute the K value that has a steady-state error $e_{ss} = 30\%$ **[SS-C]**. For the obtained K, compute the overshoot M_p (%) and the settling-time t_s (using the 2% criteria) of the closed-loop response **[TR-C]**.

b) Obtain the system root-locus diagram **[RL-C]**. Then, perform the analysis of both the transient **[TR-I]** and steady-state **[SS-I]** responses for the closed-loop control system ($K > 0$).

c) Using the K value obtained in (a), compute the corresponding phase margin M_f (degrees) and gain margin M_g (dB) **[BD-C]**. Based on the obtained margins, discuss the system stability **[BD-I]**.

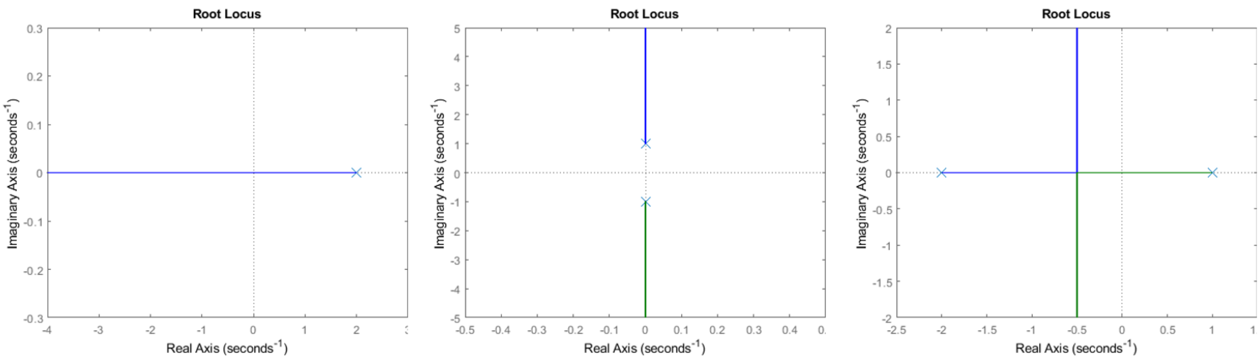
Case 2: Considering that the controller is $G_c(s) = \frac{K}{s}$:

d) Draw the root-locus diagram of the system under analysis **[RL-C]**. What K values provide a stable output?, What K values allow obtaining no complex closed-loop conjugated poles? **[RL-C/I]**.

e) Using the K value got in (a), compute the new performance specifications (M_p, t_s **[TR-C]**, e_{ss} **[SS-C]**, M_f, M_g **[BD-C]**). What happened with the system stability in relation to case 1? (provide a justified answer by analyzing the obtained specifications) **[BD-I]**.

2 Question 2 *(1 points)*

Given the following root-locus diagrams, analyze (i) the corresponding system stability, and (ii) the transient and steady-state response **[RL-I]**.



(a) (b) (c)

Figure 2: Root locus diagrams to be analyzed.

3 Question 3 *(1 points)*

Determine the closed-loop stability of the systems whose Nyquist diagrams and open-loop transfer function are presented below **[ND-I]**.

$$a)\ G(s) = \frac{K(s^2+2s+2)}{s^2-s+0.5} \qquad b)\ G(s) = \frac{K(s-1)}{(s+0.5)(s+2)} \tag{1}$$

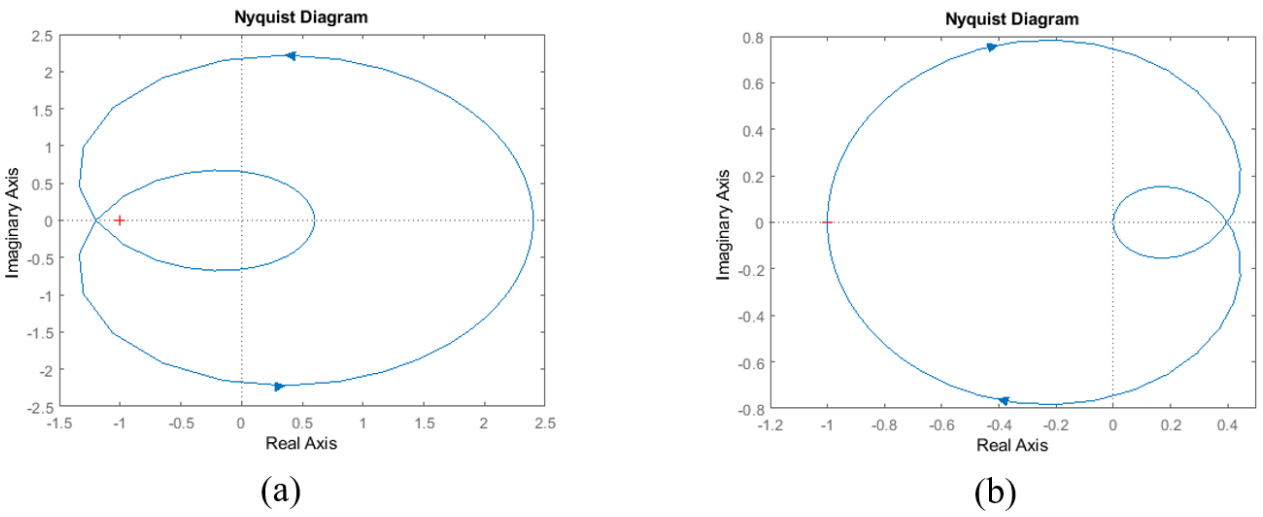


Figure 3: Nyquist diagrams to be analyzed.