ELEC-E8116 Model-based control systems

Intermediate exam 2. 15. 12. 2021

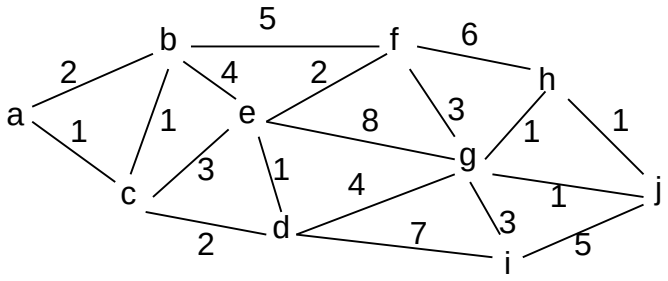
- *Write the name of the course, your name and student number to each answer sheet.*
- *There are three (3) problems and each one must be answered.*
- *Read the instructions in a separate file (Instructions), which is available in the Exam Assignment and which has also been published in advance.*
- *In problem 0 sign with your name (typesetting is enough if you use computer document) in which you assure that you follow the exam regulations.*

Each problem 1-3 gives the maximum of 5 points.

Note 1: Solutions obtained by computer are not presented and not accepted. Computer can be used in verification, but that is only for yourself to check the results, if needed.
Note 2: In many questions below you have to explain something (e.g. concepts). It is then not enough that you take some formulas, expressions or text from the course open book material; instead, you have to answer the questions in your own words such that the reviewer can see that you have really understood the issue. The answers do not have to be long, but they must be clear to the reader.

0. Write your signature confirming that you follow the exam rules.

1. **a**. Explain the concept "Principle of Optimality" (2p)
b.In the below figure the cost of moving from one node to another is given by the numbers; movement is allowed only from left to right.



Use *dynamic programming* to solve the following problem: Find the minimum cost path from node *a* to the desired final state *j*. (Copy the diagram on your paper and show clearly how you have solved the problem using dynamic programming. If you cannot present the figure in your answer sheet, then present anyway exactly each phase of your solution). (3p)

2. **a**. Explain shortly the meaning of the concept *fundamental limitations in control*? (1p)
b. List and explain in your own words the main fundamental limitations in control. You can restrict the answer to SISO systems. (2p)
c. Show the validity of the following approximative inequalities and explain what they have to do with fundamental limitations in control

$$|S| < \varepsilon \Rightarrow |GF_y| > \frac{1}{\varepsilon}, \quad |T| < \varepsilon \Rightarrow |GF_y| < \varepsilon$$ (2p)

3. Let us assume that you have to develop a controller for a linear multivariable process with *n* inputs and *n* outputs. Answer and explain the following, by using figures, formulas etc. when appropriate:

- Define Relative Gain Array (RGA) and explain how it is used in control. (2p)
- What is the difference between *decoupled* and *centralized* controllers? (1p)
- How would you design a Singular Value Decomposition (SVD)-based decoupled controller for the process? The decoupling is here considered necessary only at the zero frequency. Present the idea and also the necessary formulas. (2p)

Bonus problem: You can earn maximum 2 extra points by solving the below problem. (However, the maximum of the exam is 15 points).

Consider the pure delay term in a SISO transfer function. Derive the first order Padé approximation for it and explain how that can be used to explain one fundamental limitation in control.