LUND INSTITUTE
OF TECHNOLOGY
Lund University

Department of
AUTOMATIC CONTROL

FRTN20 – Market-driven Systems

Exam, 2012-05-25, 8.00 - 13.00

Points and grades

All answers must include a clear motivation. Answers may be given in English or Swedish. The total number of points is 25. The maximum number of points is specified for each subproblem. Preliminary grade limits:

Grade 3: 12 points
4: 17 points
5: 22 points

Accepted Aids

Standard mathematical tables, authorized "Formelsamling i reglerteknik", and pocket calculator.

Exam Results

The result will be available no later than Friday June 8 2012. The results will be posted on the notice-board at the Department of Automatic Control, 1st floor M-building. The results as well as solutions will also be available on WWW:
http://www.control.lth.se/course/FRTN20

1. Which production process type is primarily used for each of the following products (continuous, discrete, or batch)?

1. Cookies
2. Car
3. Paper
4. Electricity
5. Medicine
6. Beer

(2 p)

2. Consider a solution preparation process that consists of a tank where the mixture of water and reagent takes place, a mixer, two pumps that work one at a time according to their working hours and allow the inlet of water to the tank, a valve that allows the inlet of reagent, and a third pump that allows the outlet of the solution. Figure 1 shows the system that is to be controlled.

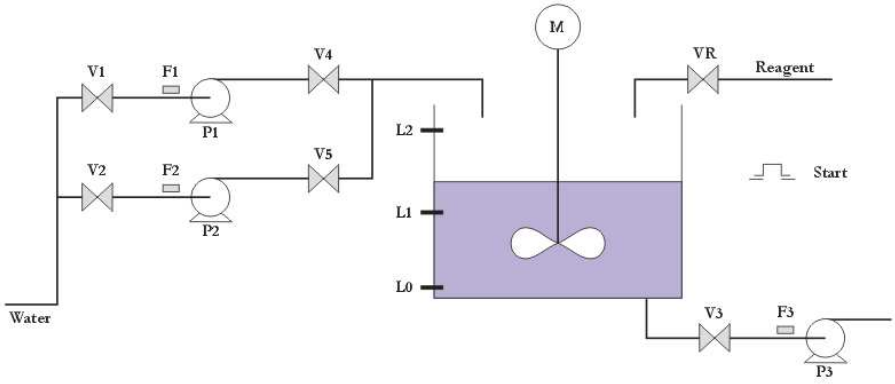

Figure 1 Solution preparation process

- Push button `Start`.
- Motor `M` for mixing of water and reagent.
- Pumps `P1` and `P2` for water inflow to the tank and `P3` for solution outflow of the tank.
- Valves `V1`, `V2`, and `V3` for water inlet of `P1`, `P2`, and `P3` respectively, `V4` and `V5` for water outlet of `P1` and `P2` respectively, `VR` valve for reagent inflow to the tank.
- Digital level sensors `L0`, `L1`, `L2`.
- Digital flow sensors `F1`, `F2`, and `F3` that detect presence of a fluid.

All sensors and actuators have positive logic, i.e., the value of the sensors or actuator is `1` when active.

Develop a Grafcet diagram that fulfils the following sequence of operations:

1. When `Start` is pressed the selection of `P1` or `P2` is done according to the working hour input `UseP1`.
2. Once a pump is selected, the inlet and outlet valve associated with it should be opened.
3. When the flow sensor associated with the selected pump indicates the presence of water in the pipe, the selected pump can be activated.
4. When the water in the tank reaches `L1`, the mixer should start and `VR` should be opened. The reagent must be supplied to the tank for 10 minutes. After that `VR` should be closed.
5. When `L2` is reached, the activated pump should stop and their associated valves should be closed.
6. When enough reagent has been added and `L2` is reached, the mixer should stop.
7. The next step is to activate `P3` to empty the tank, but first `V3` must be opened and `F3` must indicates the presence of fluid.
8. When the level goes below `L0`, `P3` should be stopped and `V3` should be closed. Then the process is ready to start again.

(3 p)

3.

a. Determine the allowed region for the linear program

$$\begin{aligned} &\text{maximize} && \begin{pmatrix} 3 & 1 \end{pmatrix} x \\ &\text{subject to} && \begin{pmatrix} 2 & 2 \\ 1 & 1 \\ 3 & 1 \\ 2 & 0 \end{pmatrix} x \preceq \begin{pmatrix} 4 \\ 3 \\ 3 \\ 3 \end{pmatrix}, x \succeq \begin{pmatrix} 0 \\ 0 \end{pmatrix} \end{aligned}$$

(1 p)

b. Solve the optimization problem. (1 p)

4. Classify the batch processes in figure 2 according to the type of batch structure (single-path, multi-path, or network) and according to the products they can produce (single-product, multi-grade, or multi-product). The products produced are A, B, and a variant of A called A'. (3 p)

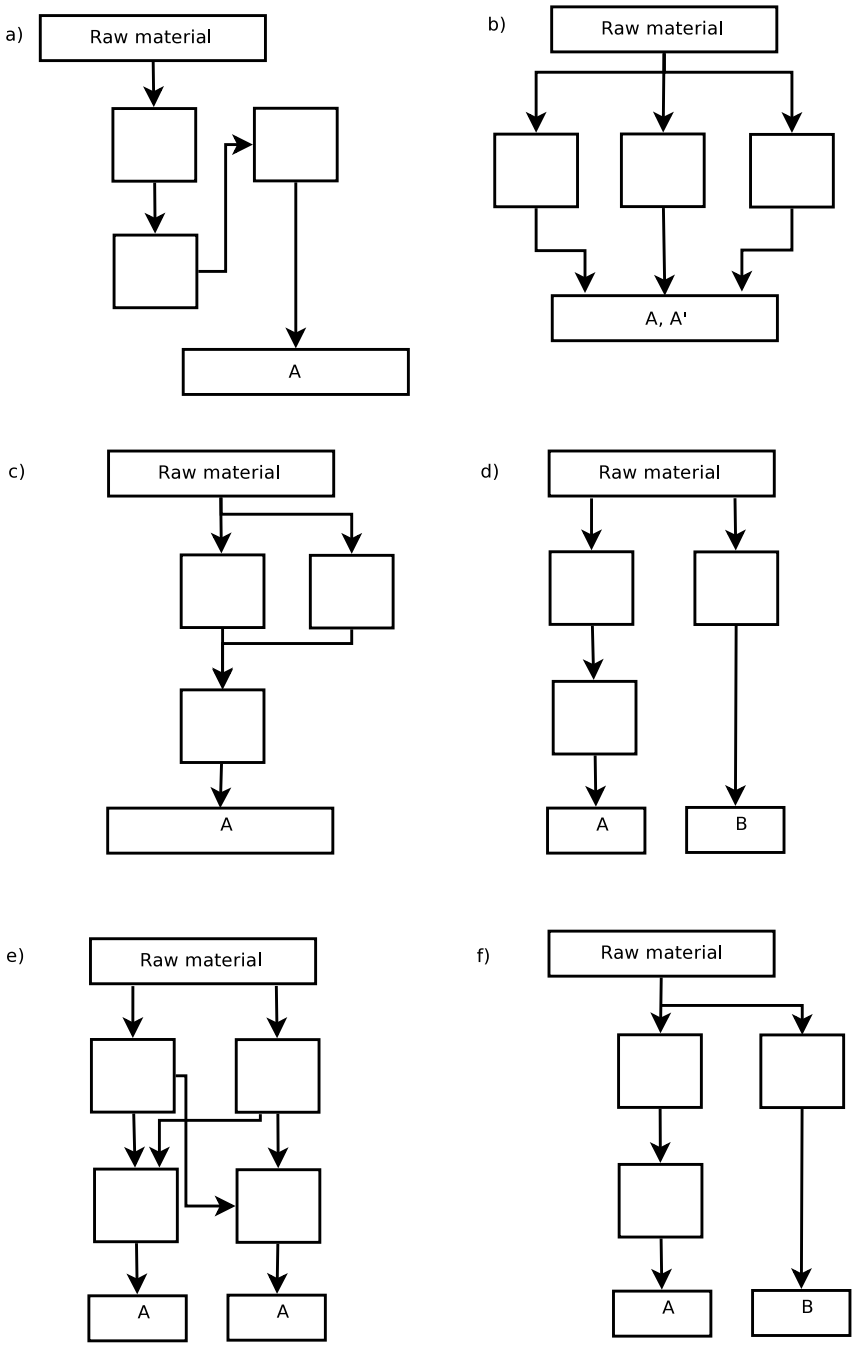

Figure 2 Batch processes for problem 4.

5.

a. This exercise is only for those project-groups that worked with the standard ISO 22400 and the project-group that worked with the standard ISA95 (IEC 62264).

Describe what a standard? Name an organization that develops standards and give your view on when it is suitable to follow the recommendations in the standard and when it is suitable to "go your own way".

Note: The groups are: Perstorp, Alfa-Laval, Scania and Tetrapak. (1 p)

b. This exercise is only for the project-groups that worked with an industrial/commersial software from a company.

Describe briefly the purpose of the software that you worked with (i.e. what purpose is it intended to be used for) and what value it can bring to customers that use the software.

Note: The groups are: Rockwell, ABB and Capacent (1 p)

c. The triangle in figur 3 shows a company from a systems perspective. Describe meaning of the triangle in detail and list 3 tasks or belong to each of the levels; Enterprise systems (Swedish: Affarssystem), MOS-level and control level (Swedish Styrsystem). (2 p)

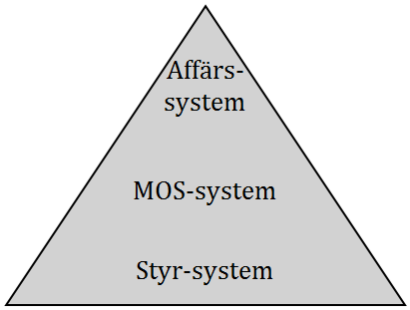

Figure 3

6. *Note:* Formulas that you might need for this problem are given at the last page of the exam.

A flowchart of the product flow at a site is given in Figure 4.

The site uses three utilities: electricity, instrument air, and vacuum system. Electricity is required at all areas, instrument air is required at area 1 and 3, and the vacuum system at area 1 and 2. The average measurements of the different utilities for 6 hours of operation are shown below. The sample time is 12 minutes.

Electricity	[1	0	1	1	0	1]
Intrument Air	[0	15	21	12	16	20]
Vacuum System	[50	102	110	20	75	90]

The disturbance limit for the Electricity at the site is defined as on/off, while the normal operation ranges for the instrument air and the vacuum system correspond to:

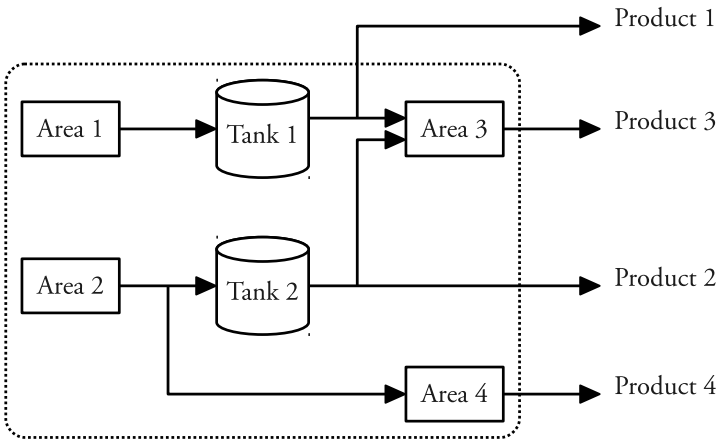

Figure 4 Flowchart of the product flow at a site.

Instrument Air: $0\text{psi} < \text{pressure} \leq 20\text{psi}$
Vacuum System: $100\text{KPa} \leq \text{pressure} \leq 3\text{KPa}$

Additional information about the products of the site is given in Table 1

Table 1 Product data

	Flow to market at max. production (m^3/h)	Contribution margin (kr/m^3)
Product 1	2	3
Product 2	0	1
Product 3	4	6
Product 4	5	2

a. Calculate the area dependence matrix A_d, the area-utility matrix A_u, the utility operation matrix U, and the utility dependence matrix U_d. What does each of these matrices represent? For the utility dependence matrix U_d consider that the instrument air and the vacuum system are both dependent on electricity, and that the vacuum system is dependent on the instrument air. Electricity does not rely on the operation of any of the other utilities. (2 p)

b. Calculate which of the utility(ies) cause(s) the greatest losses at the site? (Hint: Estimate the total revenue loss due to utilities.) You might need to know that $U_{av}^{ud} = \begin{pmatrix} \frac{5}{6} \\ \frac{5}{6} \\ 1 \end{pmatrix}$. (2 p)

7. A company produces primitive accessories (rings and necklaces) which are simply bent steel. A ring can be sold for 15 kr and requires 4 bends. A necklace can be sold of 103 kr and requires 21 bends. The company has two benders whose costs are described by figure 5. Formulate the optimization problem for maximizing the profit. (1 p)

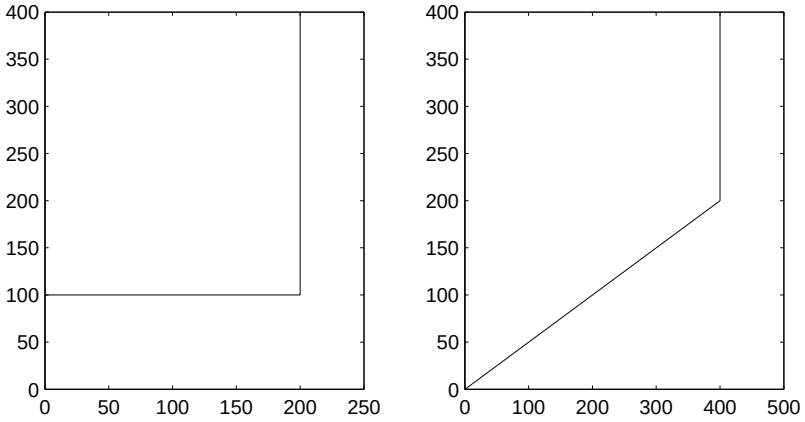

Figure 5 Cost for bender 1 (left) and bender 2 (right).

8. In the lectures on game theory we studied the Cournot model of duopoly: a situation with two companies with profit functions $u_i(q_1, q_2) = q_i(a - q_1 - q_2) - cq_i$ for $i = 1, 2$, where q_1 and q_2 are the production chosen by the respective company, c is the production cost per unit, $a - q_1 - q_2$ is the clearing price per unit and a is a constant. We showed that the Nash equilibrium is $q_1^* = q_2^* = (a - c)/3$ so the profit per company is $(a - c)^2/9$.

a. Calculate the Nash equilibrium if there instead are three companies. The profit function to be optimized for each company is $u_i(q_1, q_2, q_3) = q_i(a - q_1 - q_2 - q_3) - cq_i$, $i = 1, 2, 3$. (Hint: Because of symmetry the solution will have $q_1^* = q_2^* = q_3^*$.) (1 p)

b. Is the total profit in the triopoly market larger or smaller than in the duopoly market? (1 p)

9. Players 1 and 2 simultaneously call out one of the numbers “one” or “two”. Player 1 wins if the sum of the numbers is odd, and Player 2 wins if the sum of the numbers is even. The amount paid to the winner by the loser is always the sum of the numbers in SEK.

a. Make a table that represents the strategies of Player 1 and Player 2, and where each entrance of the table represents the payoff of Player 1. (1 p)

b. In this game one of the players has an advantage, which one is it? (1 p)

c. Can Player 1 fix his game strategy such that he wins a positive amount no matter what Player 2 calls?, How much does Player 1 win using this strategy? (2 p)

Formulas

$$
\begin{aligned}
U_{ud} &= \text{sign}\left(U + \text{sign}\left((I - U_d)(U - \mathbf{1}\mathbf{1}^T)\right)\right) \\
U_{av} &= U \cdot \mathbf{1}/n_s \\
A_{av}^{dir} &= A_{dir} \cdot \mathbf{1}/n_s \\
A_{dir} &= \mathbf{1}\mathbf{1}^T + \text{sign}\left(A_u(U - \mathbf{1}\mathbf{1}^T)\right) \\
A_{av}^{tot} &= A_{tot} \cdot \mathbf{1}/n_s \\
A_{tot} &= \mathbf{1}\mathbf{1}^T + \text{sign}\left(A_d(A_{dir} - \mathbf{1}\mathbf{1}^T)\right) \\
J_p^{dir} &= \left(\mathbf{1} - A_{av}^{dir}\right) .* q^m .* p n_s t_s \\
J_p^{tot} &= \left(\mathbf{1} - A_{av}^{tot}\right) .* q^m .* p n_s t_s \\
J_u^{dir} &= \text{diag}\left[\mathbf{1} - U_{av}^{ud}\right] \cdot A_u^T \left(q^m .* p\right) n_s t_s \\
J_u^{tot} &= \text{diag}\left[\mathbf{1} - U_{av}^{ud}\right] \cdot \text{sign}\left(A_d A_u\right)^T \left(q^m .* p\right) n_s t_s
\end{aligned}
$$