LUND INSTITUTE
OF TECHNOLOGY
Lund University

Department of
AUTOMATIC CONTROL

FRTN20 – Market-driven Systems

Exam, 2012-08-27, 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 2012-09-10. 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. Give two characteristics for each production process type: continuous, dicrete, and batch. (2 p)

2.

a. A storage room has space for 6 pallets of goods. In addition to the 6 spaces, the storage room has also space for one arriving pallet and 3 departing pallets. Pallets may be moved from arriving to stored, from stored to departing, and from arriving to departing. Model the system using a Petri Net. Draw the state where there are 4 free storage spaces, 1 arriving pallet, and 2 departing pallets. (2 p)

b. Is this Petri Net bounded? live? dead-lock free? (1 p)

3. Operating a vertical hydraulic splitter (Swe: klyv), see figure 1, is very dangerous. When it does not do what you intend, it is very tempting to use your hands to correct it while running, which might result in severe injuries. To avoid injuries, the safety system for the splitter must require the operator to use both hands to press two buttons simultaneously.

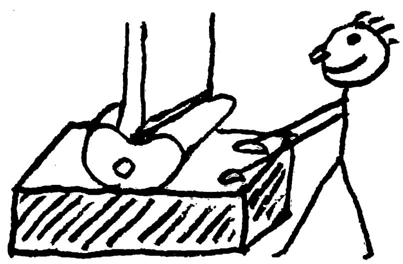

Figure 1

Inputs: isDown, isUp, b1, b2
Output: moveUp, moveDown

- When the application is started and whenever the down position is reached the splitter shall automatically move up until the up position is reached.
- When both buttons are pressed, the splitter shall move down. This has priority over moving up and if the splitter is doing so when the buttons are pressed, the moving up shall be aborted.
- moveUp must not be set while in the up position and moveDown must not be set while in the down position.
- moveUp and moveDown must never be set simultaneously.

A Grafchart application that satisfies these rules has been implemented, see figure 1, but it has two similar bugs and one undesirable behavior. When do the bugs happen and why? When does the undesirable behavior happen and why is it not desirable? Modify the application so that it behaves properly.

(2 p)

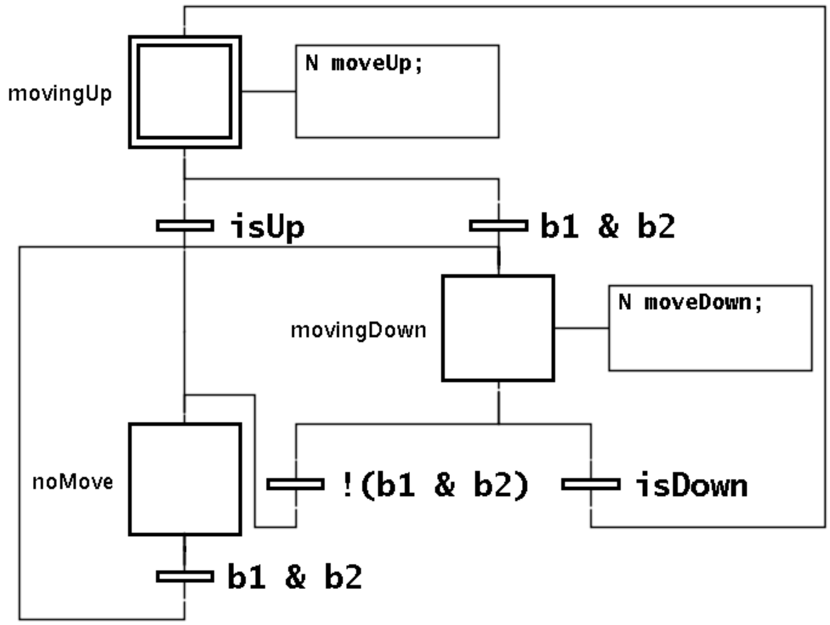

Figure 2

4. Explain the hierarchy of ISA 88 recipes, i.e. Master Recipe, General Recipe, Control Recipe, and Site Recipe. Which recipes are equipment dependent? Which physical entity does one recipy correspond to and what information is added at which level? (2 p)

5. Key Performance Indicator (KPI), är ett begrepp som används som mått för effektivitet hos ett företag. På svenska kallar man ofta detta för Nyckeltal

a. Ett nyckeltal som många företag använder sig av idag är OEE (Overall Equipment Effectiveness), på svenska kallas detta ibland även för TAK-talet. Redogör för vad detta är för ett nyckeltal. (1 p)

b. Throughput är ett annat vanligt nyckeltal som används inom industrin. Redogör för vad detta är för ett nyckeltal. (1 p)

c. Välj ut ett nyckeltal och redogör för detta. (1 p)

6. A paper company produces rolls of paper with the widths 0.75m and 1.5m which can be sold for p_1 and p_2 respectively. The rolls are cut down from 9m wide rolls of paper which can be cut into a maximum of 8 rolls. The cost of production for each roll has a fixed handling cost per roll, c_h. There is also a cost per meter width of the wide roll that is used, c_u, as well as a cost per meter width of the wide roll that is wasted (unused), c_w.

a. Express the optimization problem as an LP on matrix form:

$$\begin{aligned} \text{maximize} \quad & c^T x \\ \text{subject to} \quad & Ax \preceq b, x \succeq 0 \end{aligned}$$

(1 p)

b. What is the optimal production with $p_1 = 5$, $p_2 = 9$, $c_u = 4$, $c_w = 2$, and $c_h = 0.5$? (2 p)

7. *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 3.

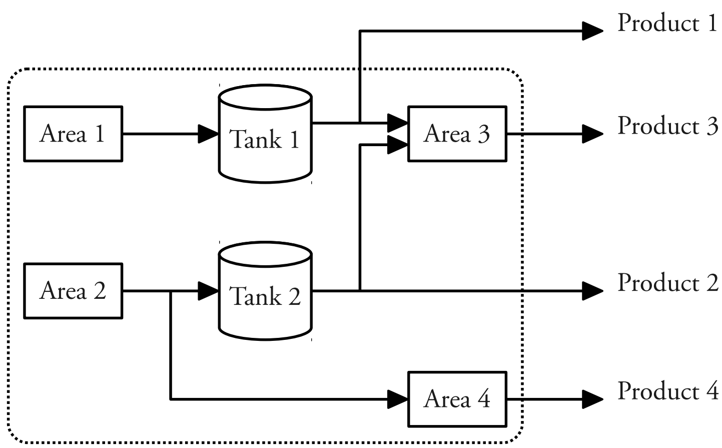

Figure 3 Flowchart of the product flow at a site.

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 bellow. 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:

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

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.

a. Calculate the utility availability considering first the utility operation matrix before removing utility dependence (U), and then the utility operation matrix when utility dependence is removed (U_{ud}). How does the availabilities change when taking utility availability into account? (2 p)

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

b. Calculate which of the utility(ies) cause(s) the greatest losses at the site? (Hint: Estimate the total revenue loss due to utilities). (2 p)

8.

a. What information do you get by the dual solution, λ^*? (0.5 p)

b. While solving a maximization LP you get the intermediate values $p = 17.3$ and $d = 17.5$ for the primal and the dual problem respectively. Is this plausible? Can they be the optimal values? (0.5 p)

c. An LP is given by

$$\begin{aligned} \text{maximize} \quad & 3x_1 + x_2 \\ \text{subject to} \quad & 2x_1 + x_2 \leq 3 \\ & x_2 \leq 1 \\ & x_1 \leq \tfrac{5}{4} \end{aligned}$$

Derive the dual function, $g(\lambda)$. (1 p)

9. Consider the following two-player game:

		Player 2: L	Player 2: R
Player 1	U	1,3/2	3,1
	D	4,2	3,3

where the first and the second number in each cell indicates Player 1's and Player 2's goal functions respectively, which is to be maximized.

a. What are the Pure Nash equilibria of the game? Justify your answer. (1 p)

b. Considering that "p" is the probability of Player 1 choosing "U", and "q" is the probability of Player 2 choosing "L", draw the best response curves for Player 1 and Player 2, and verify that these curves intersect on a line segment between 0 and 2/3. (1 p)

c. Show that Player 1 is indifferent to mixing between "U" and "D" given that Player 2 is playing "R", and that by doing so the payoff of Player 2 is reduced. (Hint: Find the payoffs of the players) (1 p)

d. Describe the Stackelberg solution to the game when Player 1 is the leader. (1 p)

Formulas

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