LUND INSTITUTE
OF TECHNOLOGY
Lund University

Department of
AUTOMATIC CONTROL

FRTN20 – Market-driven Systems

Exam, 2014-05-30, 14.00 - 19.00

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 13 2014. The results will be available through LADOK. The solutions will be available on *http://www.control.lth.se/course/FRTN20*

1.

a. What does the acronym CAPEX stand for? Give an example of a CAPEX. (1 p)

b. What does the acronym OPEX stand for? Give an example of an OPEX. (1 p)

2.

a. Name two characteristics of KPIs. (1 p)

b. Name two KPIs and describe what they can be used for. (1 p)

3. Show that $x + \overline{x}y + \overline{x}\overline{y}z = x + y + z$. (2 p)

4. The company *Stellar Brushes* produces two kinds of toothbrushes; Super and Nova. Manufactuing a toothbrush consists of three major steps; forming the handle and head of the brush, adding bristles to the head, and packaging. The total time available in the forming machine is 22 time units, 96 time units in the bristling machine, and in the packaging machine it is 60 time units. One Super toothbrush requires 1 units in the forming machine, 12 units in the bristling machine, and 5 units in the packaging machine, while for Nova it is 2 units in the forming machine, 4 units in the bristling machine, and 5 units for packaging. The revenue for the company from Super is 7 and for Nova it is 4.

a. Determine the optimal production rate of Super and Nova and calculate the revenue for the company. (2 p)

b. The company has an opportunity to increase the capacity of the packaging machine. Which is the lowest capacity that will make the production independent of the packaging machine, given the capacity of the other machines do not change? (1 p)

c. The main competitor of Stellar Brushes introduces a new toothbrush on the market, forcing Stellar Brushes to lower their price on Super. Based on the information in subproblem a, what is the lowest revenue that Stellar Brushes can accept for Super before they must change their production mix. You can assume that a noninteger production rate symbolizes an average production rate. What is the revenue at the breakpoint? (1 p)

5. An Integrated Circuit (IC) is a key component in all electronic devices today. The manufacturing process is highly automated with many steps.

The first step in IC production is to make thin disc of silicon called wafer. On the wafer there can be hundred or thousands of ICs depending on the size of the wafer and the IC it self. On the wafer, the components for each IC are added in multiple steps. When all components are added, the ICs are tested and the functioning ones are cut out of the wafer and sent to packaging before deliver to the customer.

a. Classify the manufacturing process as batch, continuous, or discrete. Motivate your answer. (1 p)

b. Some ICs on the wafer will be malfunctioning due to issues with the manufacturing process. If a malfunctioning IC is sent to a customer, the final product (the phone, computer, etc.) will not work. Therefore it is important to find bad ICs before they are being packaged. Your task is to draw the testing and packaging process described below using Grafcet.

The testing/packaging process starts when the operator loads a container of several wafers in the testing machine and presses a button, B=1. The machine loads a single wafer into the testing device by setting LOAD=1, a sensor returns a signal, W=1, when the wafer is loaded. The next step is the measuring process which is initiated by setting MEAS = 1. A control signal S returns the result of the measurement, S = 0 indicates a bad IC while S=1 indicates a good one. The bad ones are left without further action. The good ones are cut out and sent to packaging by setting the signal CUT = 1. A signal P = 1 indicates that the machine is done with the packaging. Independent of whether the IC was good or bad, the measuring device is moved to the next IC by setting MOVE = 1 and the measurement can begin when M = 1. The measurement sequence then starts over again. If there are no more units to test, a signal E = 1 instead of M and the machine is set in idle mode.

(2 p)

6. A manufacturing plant consists of five areas and one buffer tank with area dependencies as in Figure 1. The manufacturing areas need electricity, nitrogen, and water. All areas need electricity, while area 1, 2, and 4 need water, and area 2 and 3 need nitrogen.

Note: UDM formulas are available on the last page of the exam.

a. The impact of disturbances in supply of utility can be studied using UDM. Name some pros and cons of the UDM framework. (1 p)

b. What is the area utility matrix for this problem? (1 p)

c. The utility measurement for electricity (on/off), nitrogen (concentration),

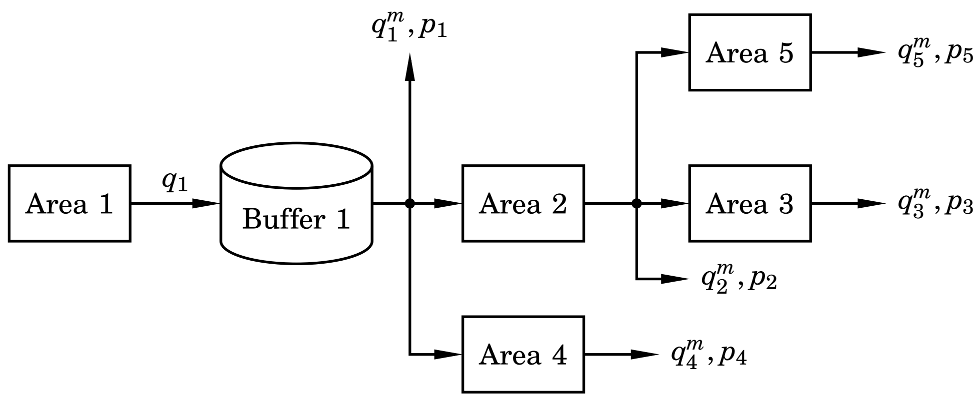

Figure 1 The production site for problem 6

and water (pressure), measured once every hour is

$$\begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 \\ 38 & 41 & 45 & 36 & 32 & 31 & 35 & 39 \\ 4.8 & 5.1 & 5.5 & 5.4 & 4.9 & 5.1 & 4.8 & 5.5 \end{bmatrix}$$

In order for the areas to operate, the electricity must be on, the concentration of nitrogen must be $\geq 35\%$, and the water pressure must be ≥ 5 bar. Specify the utility operation matrix. (1 p)

d. Which area has the largest direct loss if the flow to market is $q_m = [3 \quad 6 \quad 2 \quad 0 \quad 5]^T$ and the price is $p = [1 \quad 4 \quad 3 \quad 1 \quad 6]^T$. (1 p)

7. The local company Finn Pizza has been a great success and has gathered enough funds to expand with new factories all over the world. In their current factory, the recipy for baking pizza is strongly coupled to the production equipment and the amounts of each ingredient are hard coded, for example "100 grams of yeast". The flow through the production process is linear, that is all pizzas pass through the same stations. Depending on which kind of pizza is being made (Capricciosa, Hawaii, Vesuvio, ...), different ingrendients are added at the stations. Each new factories will produce one or more pizza kind and will have much higher throughput with parallel preparation and several ovens where a prepared pizza can go into either oven.

a. Draw the plant structure for both the current and the new factories and classify them (single-path, multi-path, or network). (2 p)

b. On what level is the recipy in the current factory? (General, Site, Master, or Control) For each other recipy type, motivate why is the recipy is not on this level. (2 p)

8. The Cornout model of Duopoly has two production firms deciding on individual production quantities Q_1 and Q_2. After the decisions $Q_i \geq 0$ are taken, the selling price per unit is decided by the market, for simplicity modeled here via the linear price curve $P(Q_1, Q_2) = 2 - (Q_1 + Q_2)$. Assume that the two firms have unit production cost $0 \leq c_i \leq 2$, the profit for firms i is hence

$$u_i(Q_1, Q_2) = (2 - c_i - (Q_1 + Q_2))Q_i$$

a. Determine the best response functions $B_1(Q_2)$ and $B_2(Q_1)$. (2 p)

b. The game has a pure Nash equilibrium (Q_1^*, Q_2^*). Determine how (Q_1^*, Q_2^*) depends on (c_1, c_2). Also draw a diagram with c_1 and c_2 on the two axes describing the three regions where the Nash-equilibrium satisfies

- $Q_1^* > 0, Q_2^* = 0$ (monopoly sitution for firm 1)
- $Q_1^* = 0, Q_2^* > 0$ (monopoly sitution for firm 2)
- $Q_1^* > 0, Q_2^* > 0$ (duopoly sitution).

(2 p)

Formulas

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

Note: $.*$ *means element-wise matrix multiplication.*