IMPERIAL COLLEGE LONDON

EE4-57
EE9-CS2-2

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2018

MSc and EEE/EIE PART IV: MEng and ACGI

Corrected copy

DISCRETE-EVENT SYSTEMS

Tuesday, 1 May 10:00 am

Time allowed: 3:00 hours

There are FOUR questions on this paper.

Answer ALL questions.

All questions carry equal marks

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible	First Marker(s) :	D. Angeli
	Second Marker(s) :	E.C. Kerrigan

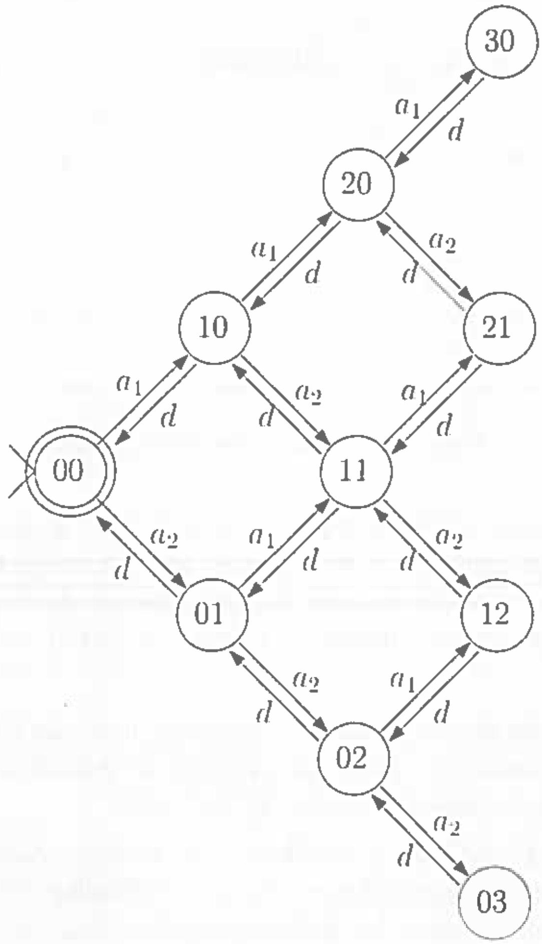

Figure 1.1 Automaton G: transition diagram.

1. Two queues, accepting clients in parallel, have a total maximum capacity of 3, and are modeled according to the Finite Nondeterministic Automaton G shown in Fig. 1.1. In particular, the set of events is $E = \{a_1, a_2, d\}$, denoting respectively arrivals for queue 1, 2 and departures. The initial (and terminal state), is the state 00 which represents both queue being empty.

   a) Denote by $x_1 \equiv x_2$ equivalence between states, (viz. $\mathscr{L}_m(G|x_1) = \mathscr{L}_m(G|x_2)$ and $\mathscr{L}(G|x_1) = \mathscr{L}(G|x_2)$). Build a table with all possible pairs of states, and flag those pairs which are not equivalent because one state is terminal and the other is not. [2]

   b) Within the same table, mark as non-equivalent those pairs of states which have different sets of enabled events. [3]

   c) Then, iteratively, flag all pairs of states (x_1, x_2) for which there exists an arrival event such that $(f(x_1, a_i), f(x_2, a_i))$ is flagged $(i = 1, 2)$. [4]

   d) Show that, after the previous steps, all unflagged pair of states are equivalent and find the equivalence classes of "$\equiv$" for the automaton G previously defined. [5]

   e) Find an automaton $G_{\min}$, which generates and marks $\mathscr{L}(G)$ and $\mathscr{L}_m(G)$ (respectively), but has the lowest possible number of states. [6]

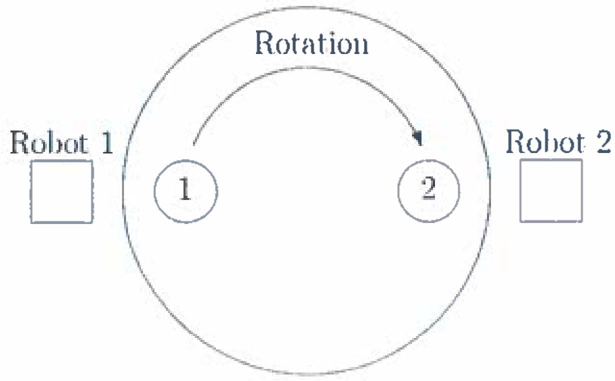

Figure 2.1 Rotating platform diagram

2. A rotating platform can host up to 2 tools in slots 1 and 2 respectively (see Fig. 2.1). Two robots, which are statically anchored at their position, can pick (event p_i) or release (event r_i) tools at such positions when the corresponding slot is non-empty (with $i = 1,2$). When an event r occurs (rotation), a clockwise rotation of 1 slot (180 degrees) occurs.

a) Model the occupancy of the slots at the 2 positions (as a function of the events described above) as a Finite Deterministic Automaton G. Assume the initial state is one in which all slots are full with tools. [6]

b) Assume next that event r is unobservable. Design a diagnoser that is capable, after a string of events in $\{p_1, r_1, p_2, r_2\}^*$, of deciding whether or not an r event has occured. (2 marks for labelling automaton G_L, 6 marks for correct parallel composition between platform G and labelling automaton G_L, 6 marks for correct observer automaton). [14]

3. Consider the Petri Net with 4 places and 4 transitions encoded by the following *Pre* and *Post* matrices:

$$Pre = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

$$Post = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 \end{bmatrix}.$$

a) Compute the incidence matrix C. [3]

b) Compute the minimal P-semiflows of the net. [5]

c) Is the network structurally bounded ? (Justify your answer). [3]

d) Consider the initial marking $M = [1,1,1,1]$. Compute the Reachable set and the associated transition diagram. [5]

e) Discuss the Reversibility of the net from the considered initial marking, on the basis of the diagram derived previously. [4]

4. Machine A works on the following cycle of events to the production of one type of pieces: p_{1a} (pick tool 1), r_{1a} (release tool 1), p_2 (pick tool 2), r_2 (release tool 2). Machine B works instead on the following cycle of events, to the production of a different type of pieces: p_{1b} (pick tool 1), r_{1b} (release tool 1), p_3 (pick tool 3), r_3 (release tool 3).

a) Model each machine as a finite deterministic automaton and denote these automata by G_A and G_B, respectively. [4]

b) Compute G, the parallel composition of G_A and G_B. [4]

c) Model, as a finite deterministic automaton G_{spec}, the specification that p_1 events (either a or b) must always alternate with r_1 events (either a or b). Argue that this allows to model tool 1 being shared by the two machines. [4]

d) Compute $G||G_{spec}$ and show its transition diagram. [4]

e) Is the language $\mathscr{L}(G||G_{spec})$ controllable if the set of uncontrollable events $E_{uc} = \{r_{1a}, r_{1b}, r_2, r_3\}$? (Justify your answer). [4]