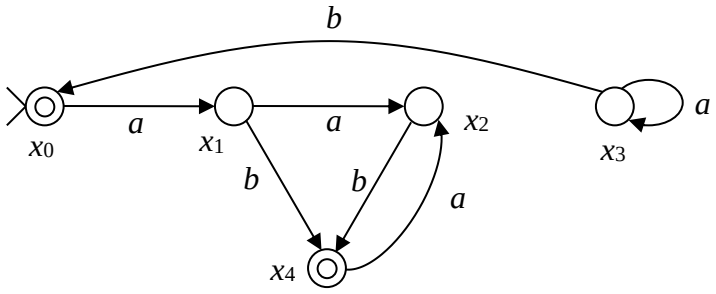
Analysis and Control of Cyber-Physical Systems

Midterm exam — 21 April 2022

Problem 1. [6 pts] Consider the deterministic finite automaton G shown below.



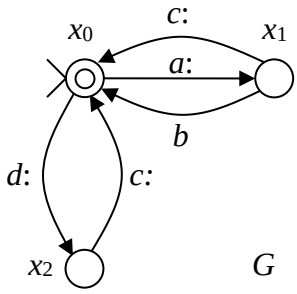
(a) *(1 pts)* Determine the algebraic representation G.

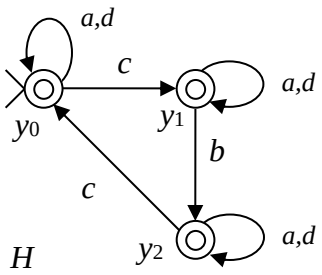
(b) *(3 pts)* Discuss which of the following properties this DFA satisfies: reachable, coreachable, blocking, with or without dead states, trim, reversible, complete.

(c) *(2 pts)* Discuss how the following languages are ordered by subset inclusion $\subseteq$ explaining when identity holds:

$$L(G), \quad L_m(G), \quad pref(L(G)), \quad pref(L_m(G)).$$

Problem 2. [10 pts] Consider a plant G modeled by the DFA on alphabet $E = \{a, b, c, d\}$ shown below. The set of controllable events is $E_c = \{a, c, d\}$. The systems should be controlled to enforce the language specification described by the specification automaton H also shown in figure.





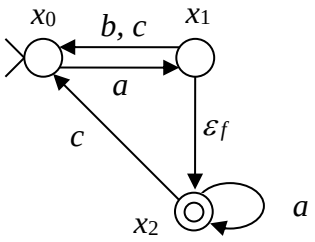
(a) *(1 pts)* Construct the extended specification automaton $\hat{H}$ and discuss how its generated and accepted languages are related to those of the specification automaton H.

(b) *(5 pts)* Discuss if this specification is controllable. If not, identify a weakly forbidden word w which can be uncontrollably extended to a forbidden word w'.

(c) *(2 pts)* Determine a maximally permissive supervisor S capable of enforcing this specification.

(d) *(2 pts)* Determine a maximally permissive and *non-blocking* supervisor S' capable of enforcing this specification.

Problem 3. [11 pts] A manufacturing system prone to failures is modeled by the DFA G shown in the figure below. The set of observable events is $E_o = \{a, b, c\}$ and the set of unobservable and fault events are $E_{uo} = E_f = \{\varepsilon_f\}$.



(a) *(1 pts)* Determine the words in E_o^* that are observed when the following strings are generated:

$$i) \quad s_1 = a\varepsilon_f c; \qquad\qquad ii) \quad s_2 = abab.$$

(b) *(2 pts)* Determine for each observed word $w \in E_o^*$ listed below the set $\mathcal{S}(w)$ of strings consistent with w and the set $\mathcal{X}(w)$ of states consistent with w:

$$i) \quad w_1 = a; \qquad ii) \quad w_2 = aa; \qquad iii) \quad w_3 = ac; \qquad iv) \quad w_4 = acc.$$

(c) *(5 pts)* Determine the diagnoser $Diag(G)$. What is the diagnosis state $\varphi(w)$ for each of the words listed below?

$$i) \quad w_1 = acac; \qquad ii) \quad w_2 = abab; \qquad iii) \quad w_3 = abaa.$$

(d) *(3 pts)* Discuss if the diagnoser contains uncertain or indeterminate cycles and if the fault is diagnosable. If not, determine an ambiguous string $s = u\varepsilon_f v \in L(G)$ where v can be arbitrarily long.

Problem 4. [3 pts] How many different languages can be *accepted* by a DFA with only one state and alphabet $E = \{a, b\}$? List them all.