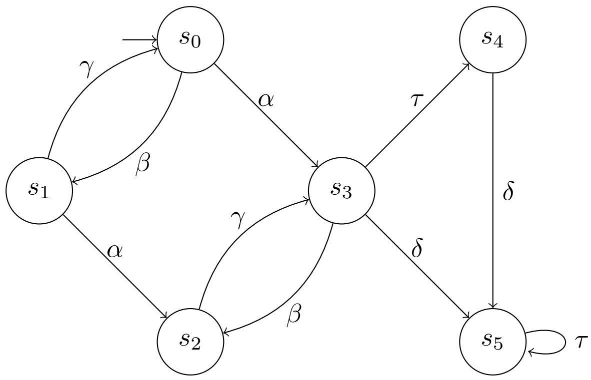
Prof. Dr. Ir. Dr. h. c. Joost-Pieter Katoen
Sebastian Junges, Lutz Klinkenberg

Model Checking
(Winter Term 2019/2020)
— Exercise Sheet 9 (due 17th January) —

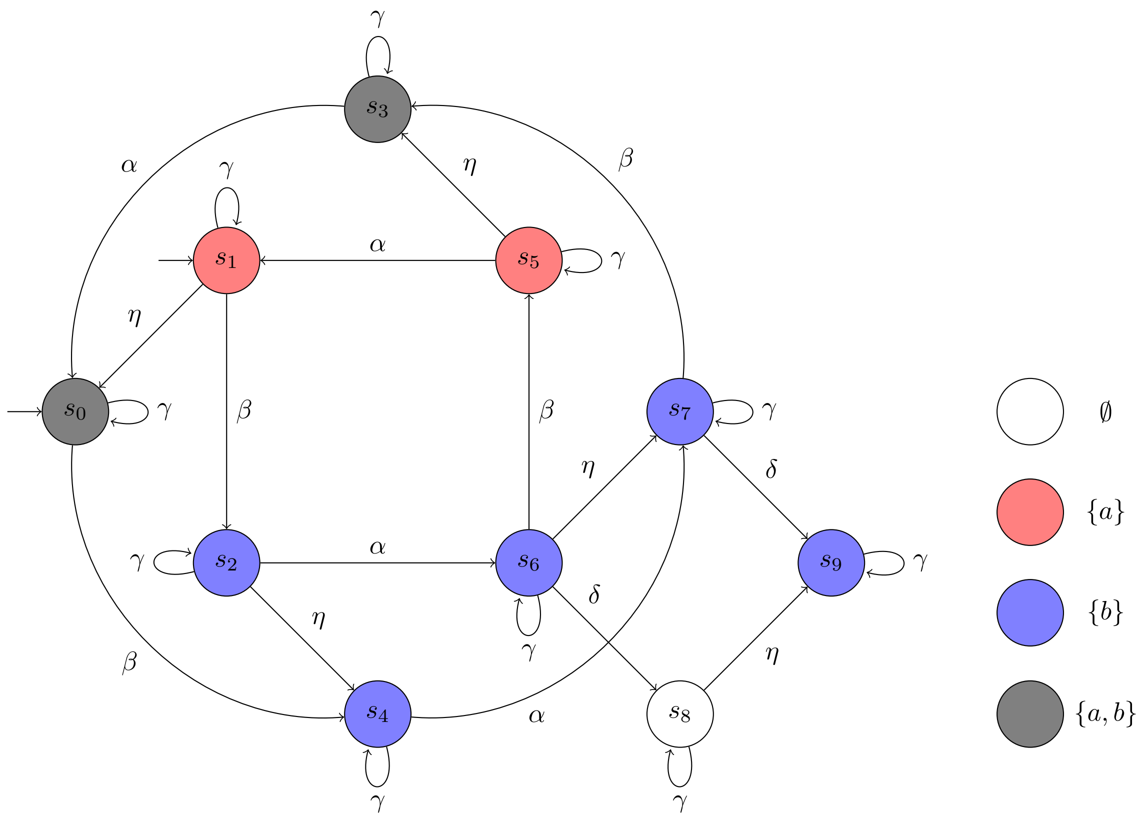
Exercise 1

Consider the following transition system TS with action set $Act = \{\alpha, \beta, \gamma, \delta, \tau\}$ in which all states are equally labeled. Determine for each pair of unequal actions whether they are independent.



Exercise 2

Consider the transition system TS depicted below.



Further, assume the following ample sets.

(i) $ample(s_1) = \{\beta\}$

(ii) $ample(s_2) = \{\alpha\}$

(iii) $ample(s_5) = \{\alpha, \gamma\}$

(iv) $ample(s_6) = \{\alpha, \beta, \delta\}$

and $ample(s_i) = Act(s_i)$ for all other states.

(a) For each of the given ample sets, indicate whether it satisfies conditions (A1) to (A3). Justify your answer.

(b) Check if condition (A4) is satisfied for the given ample sets. Justify your answer.

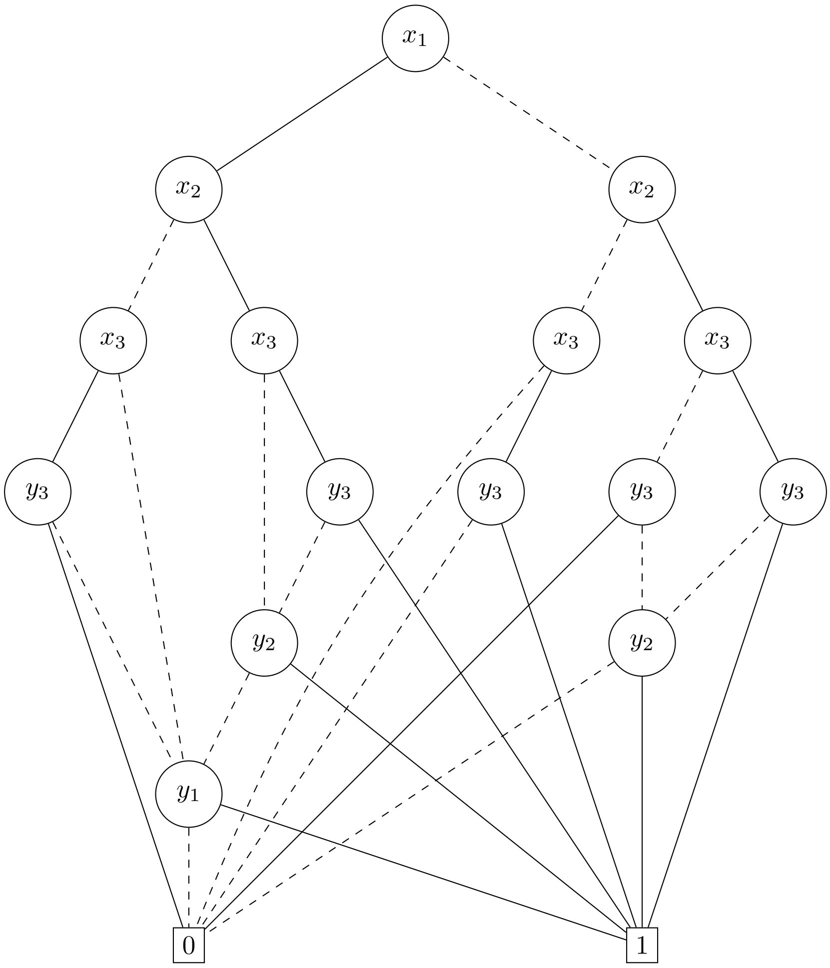
(c) In case some of the conditions (A1) to (A4) do not hold, provide a minimal extension of the ample sets to fix the issue. Justify your changes.

Exercise 3

Consider the ROBDD depicted below.

a) We consider a new variable ordering given by $y_3 < x_3 < x_2 < y_2 < x_1 < y_1$. Give the resulting **R**OBDD.

b) Determine the boolean function $f(x_1, x_2, x_3, y_1, y_2, y_3)$ that the ROBDD represents.

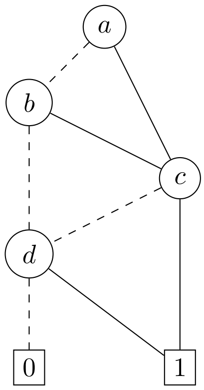


Exercise 4

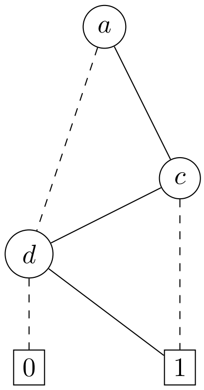
Perform the following operations on ROBDDs. Your result should always be a **reduced** OBDD. Provide the intermediate steps of your computations. In particular, indicate which of the three rules for reducing OBDDs you apply. The variable ordering is given by $a < b < c < d$.

a) Compute $F \vee G$ for the following ROBDDs F and G.
Hint: Recall the similarities between ROBDDs and DFAs. A (possibly non-reduced) OBDD for $F \vee G$ can be constructed similarly to the well-known product construction for DFAs.

F :

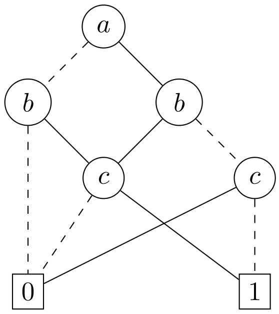


G :



b) Compute $H|_{b=1}$ for the ROBDD H given below

H :



c) Compute $\exists a.(\exists d.f(a, b, c, d))$ in the form of an ROBDD for the function f defined by the ROBDD below.
Hint: $\exists a.g(a, \dots) \equiv g(0, \dots) \vee g(1, \dots)$

f :