Course “Formal Methods” TEST

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Name (please print):

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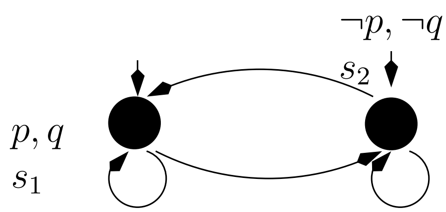
1

Consider the following Kripke Model M:



For each of the following facts, say if it is true or false in CTL*.

(a) $M \models \mathbf{A}(\mathbf{GF}p \rightarrow \mathbf{GF}q)$

(b) $M \models \mathbf{A}(\mathbf{GF}p)$

(c) $M \models \mathbf{A}(\mathbf{FG}\neg p)$

(d) $M \models \mathbf{A}(\neg p \mathbf{U} q)$

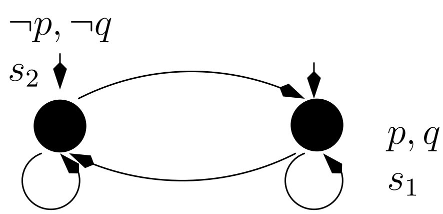
[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

2

Consider the following Kripke Model M:



For each of the following facts, say if it is true or false in CTL.

(a) $M \models \mathbf{EG}p$

(b) $M \models \mathbf{AF}\neg p$

(c) $M \models \mathbf{AGAF}q$

(d) $M \models \mathbf{E}(\neg p \mathbf{U} q)$

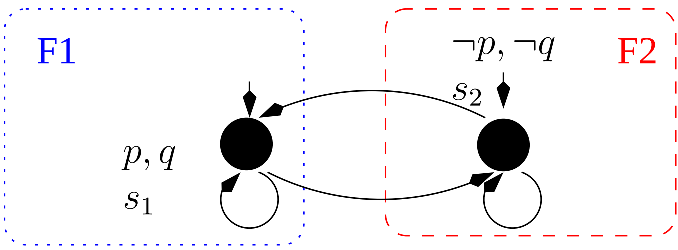
[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

3

Consider the following fair Kripke Model M:



For each of the following facts, say if it is true or false in CTL.

(a) $M \models \mathbf{EG}p$

(b) $M \models \mathbf{AF}\neg p$

(c) $M \models \mathbf{AGAF}q$

(d) $M \models \mathbf{E}(\neg p \mathbf{U} q)$

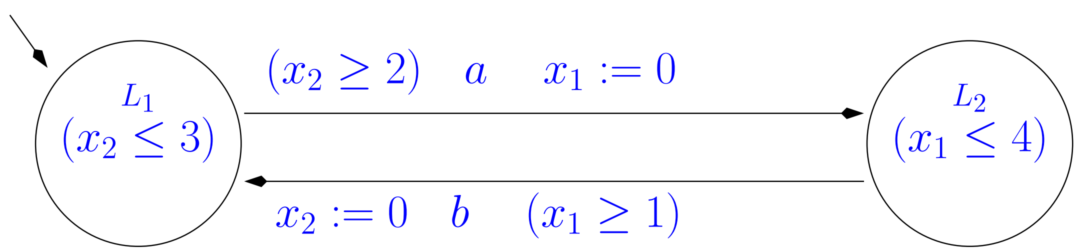
[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

4

Consider the following timed automaton A:



Considere the correponding Region automaton R(A). For each of the following pairs of states of A, say if the two states belong to the same region. (States are represented as $(Location, x_1, x_2)$.)

(a) $s_0 = (L_1, 4.2, 3.5)$, $s_1 = (L_1, 4.5, 3.2)$

(b) $s_0 = (L_1, 1.0, 2.0)$, $s_1 = (L_1, 1.0, 2.7)$

(c) $s_0 = (L_2, 0.2, 1.2)$, $s_1 = (L_2, 0.5, 1.5)$

(d) $s_0 = (L_2, 3.8, 0.7)$, $s_1 = (L_2, 4.4, 0.4)$

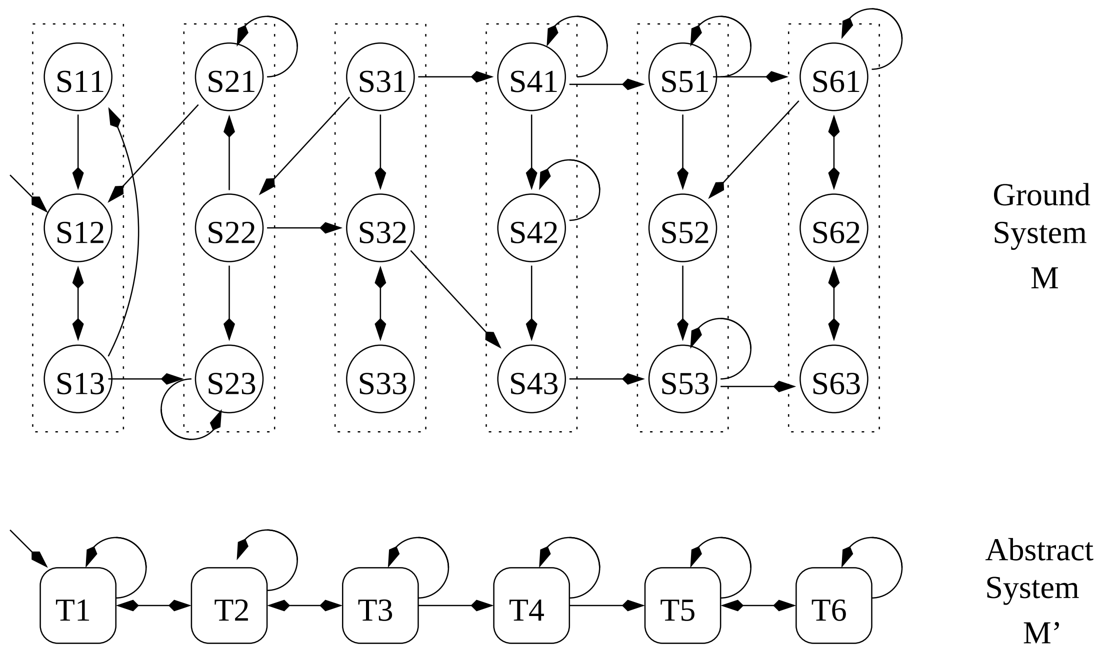
[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

5

Consider the following pair of ground and abstract machines M and M':



and the abstraction $\alpha : M \longmapsto M'$ which, for every $j \in \{1, ..., 6\}$, maps $Sj1, Sj2, Sj3$ into Tj.

For each of the following facts, say which is true and which is false.

(a) M simulates M'.

(b) M' simulates M.

(c) If φ is an LTL formula and $M' \models \varphi$, then $M \models \varphi$

(d) If φ is an LTL formula and $M \models \varphi$, then $M' \models \varphi$

[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

6

Consider the following transition relation inside a NuXMV program:

```
(...)
TRANS
(b0 -> next(b0)) & (b1 -> next(b1)) & (b2 -> next(b2)) & (b3 -> next(b3))
(...)
```

Adopting a suitable variable ordering of your choice, draw the OBDD representing such transition relation.

Use the following notation: B_i for `bi` and B_i' for `next(bi)`, for every $i \in [0, ...3]$.

[SCORING: [0...100], 100 pts for a correct answer. No penalties for a wrong answer..]

7

Given the function

OBDD $Preimage$(**OBDD** X)

which computes symbolically the preimage of a set of states X wrt. the transition relation of the Kripke model, write the pseudo-code of the function:

OBDD $CheckEU$(**OBDD** X_1, X_2)

computing symbolically the (OBDD representing) the denotation of $\mathbf{E}[\varphi_1 \mathbf{U} \varphi_2]$, X_1, X_2 being the OBDDs representing the denotation of φ_1 and φ_2.

[SCORING: [0...100], 100 pts for a correct answer. No penalties for a wrong answer..]

8

Given the following LTL Model Checking problem $M \models \varphi$ expressed in NuXmv input language:

```
MODULE main
VAR x : boolean; y : boolean;
INIT (x & !y)
TRANS ((next(y) <->  x)) & (next(x) <-> (y))
LTLSPEC G ! (x <-> y)
```

1. Write a Boolean formula corresponding to the Bounded Model Checking problem with k = 2., and say if it is satisfiable.
2. What are the diameter and the recurrence diameter of this system?
3. *From the previous answers* (and only from them!) we can conclude:

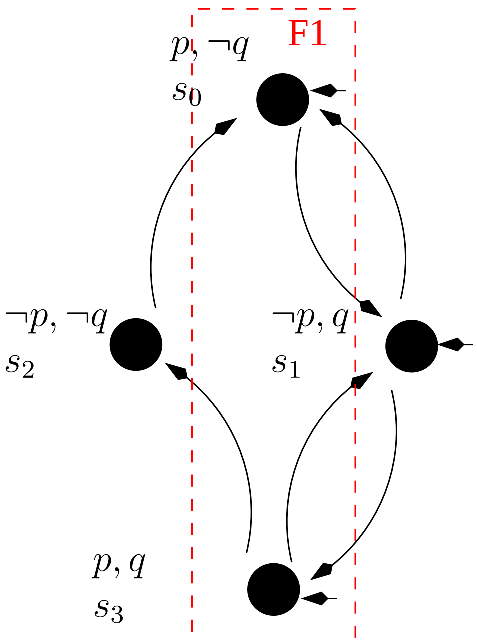
   (a) that $M \models \varphi$;
   (b) that $M \not\models \varphi$;
   (c) nothing.

   Briefly explain your choice.

[SCORING: [0...100], (1,2): +25pts each. (3) 50pts. No penalties for wrong answers.]

9

Consider the following fair Kripke model M:



Convert it into an equivalent Buchi automaton.

[SCORING: [0...100], 100 pts for a correct answer, no penalties for wrong anwers.]

10

Given the following finite state machine expressed in NuSMV input language:

```
MODULE main
VAR
  v1 : boolean;
  v2 : boolean;
  v3 : boolean;
ASSIGN
  init(v1) := FALSE;
  init(v2) := FALSE;
  init(v3) := TRUE;
TRANS
  (next(v1) <-> v2) &
  (next(v2) <-> v3) &
  (next(v3) <-> v1)
```

and consider the property $P \stackrel{\text{def}}{=} (v_1 \wedge \neg v_2 \wedge \neg v_3)$. Write:

(a) the Boolean formulas $I(v_1, v_2, v_3)$ and $T(v_1, v_2, v_3, v_1', v_2', v_3')$ representing respectively the initial states and the transition relation of M.

(b) the graph representing the FSM.
(Assume the notation "$v_1v_2v_3$" for labeling the states: e.g. "101" means "$v_1 = 1, v_2 = 0, v_3 = 1$".)

(c) the Boolean formula representing symbolically $\mathbf{EX}P$. [The formula must be computed symbolically, not simply inferred from the graph of the previous question!]

[SCORING: [0...100], +25pts each for questions (a) and (b), 50pts question (c), no penalties for wrong answers.]