# Course “Formal Methods”
# or
# Joint Courses “Automated Reasoning & Formal Verification”
# TEST

Roberto Sebastiani
DISI, Università di Trento, Italy

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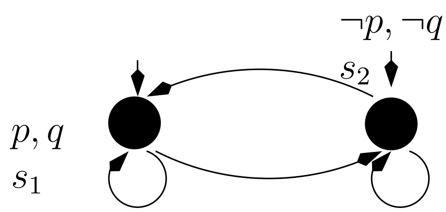
857976918

Name (please print):

Surname (please print):

# 1

Consider the following Kripke Model $M$:




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

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

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

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

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

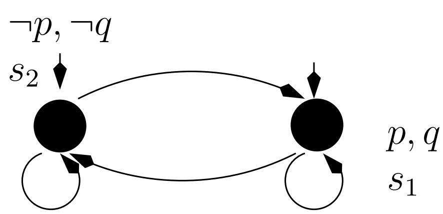
[SCORING [0...100]:

- +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.

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

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

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

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

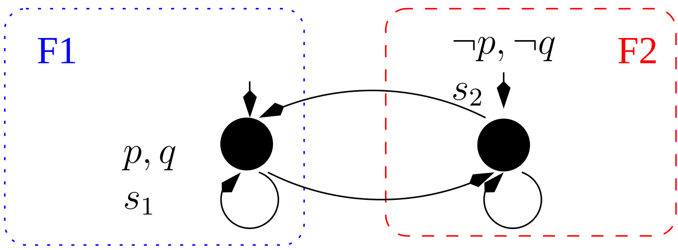
[SCORING [0...100]:

- +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 CDCL SAT solving. For each of the following sentences, say if it is true or false.

($a$) Let $\varphi$ be the CNF input Boolean formula, and $C$ denote a generic clause learned during the process. Then $\varphi \models C$.

($b$) During the CDCL SAT solving process, the formula may contain an exponential number of learned clauses.

($c$) Let $C$ be a conflict clause learned using the original backjumping&learning strategy. Then $C$ contains at least one literal whose negation was unit-propagated in the current branch.

($d$) Let $C$ be a conflict clause learned using the state-of-the-art backjumping&learning strategy. Then $C$ contains at most one literal whose negation was unit-propagated in the current branch.

[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 $M'$:

$M$:

```
MODULE main
VAR
  v1 : boolean;
  v2 : boolean;
  v3 : boolean;
ASSIGN
  init(v1) := TRUE;
  init(v2) := TRUE;

TRANS
  (next(v1) <-> v2) &
  (next(v2) <-> v3)
```

$M'$:

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

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

($a$) $M$ simulates $M'$.

($b$) $M'$ simulates $M$.

($c$) for every Boolean property $\varphi$ on `v1,v2`, if $M \models \mathbf{AG}\varphi$, then $M' \models \mathbf{AG}\varphi$,

($d$) for every Boolean property $\varphi$ on `v1,v2`, if $M \models \mathbf{EF}\varphi$, then $M' \models \mathbf{EF}\varphi$,

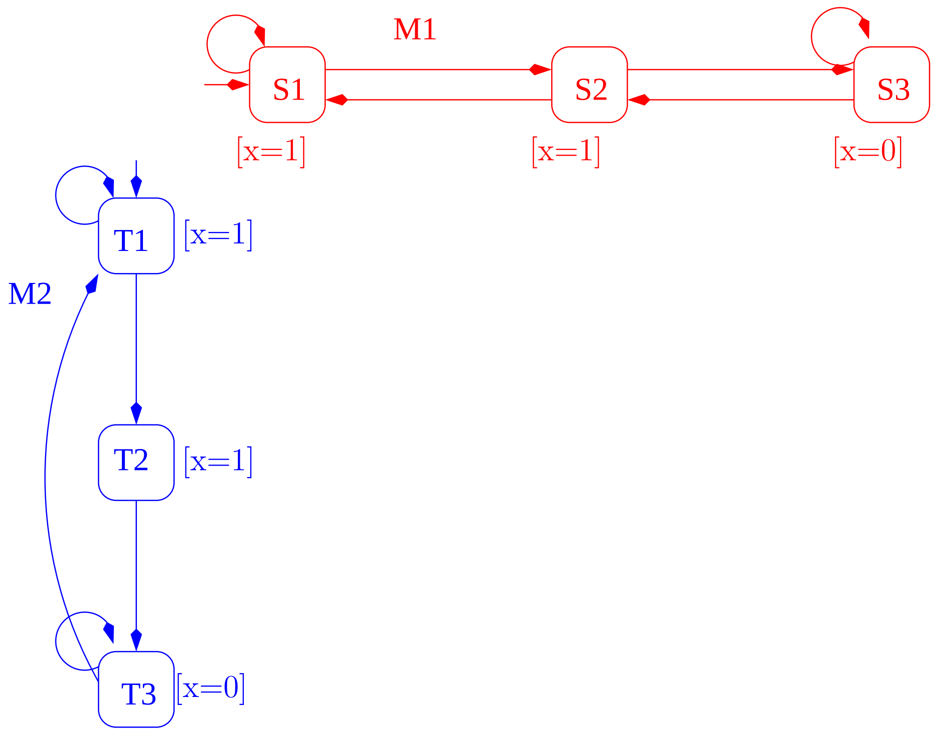
[SCORING [0...100]:

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

]

# 6

Consider the following two Kripke models $M1$ and $M2$, which share the variable x:




Compute and draw the graph of the synchronous product of $M1$ and $M2$.
Note: unreachable and deadend states should be removed.

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

# 7

Consider the LTL formula $\varphi \stackrel{\text{def}}{=} (\neg p \mathbf{R} \neg q) \rightarrow \mathbf{G} r$

$(a)$ rewrite $\varphi$ into Negative Normal Form

$(b)$ find the initial states of a corresponding Generalized Büchi Automaton (for each state, define the labels of the incoming arcs and the "next" section.)

$(c)$ How many distinct sets of accepting states will the final Generalized Büchi Automaton have?

[SCORING: [0...100], (a): +25pts for correct answer, (b) +50 points, (c) +25points. No penalties for wrong answers..]

# 8

Let $M$ be a **fair** Kripke model, which is represented symbolically by the OBDDs $I$, $T$, $FT \stackrel{\text{def}}{=} \{F_1, ..., F_k\}$ (which for simplicity we assume to be global variables), representing respectively the initial states, the transition relation and the fairness properties.

We assume it is given an implementation of the standard symbolic CTL Model Checking functions:

**OBDD** Check_EX(**OBDD** X)
**OBDD** Check_EG(**OBDD** X)
**OBDD** Check_EU(**OBDD** X,Y)

Write the pseudo-code of the fair symbolic CTL Model Checking function:

**OBDD** Check_FairEG(**OBDD** X)

which handles the **EG** operator.

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

# 9

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

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

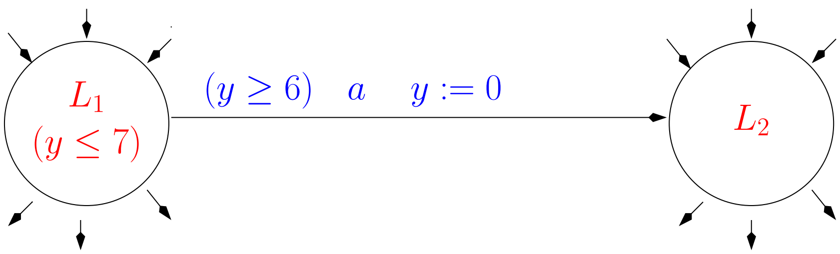
1. Write the Boolean formulas describing the k-induction encoding of the problem, with k = 1.
2. Say if they are satisfiable or not. If yes, show a model. If not, explain why.
3. From the previous answers we can conclude:

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

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

# 10

Consider the following switch $e$ in a timed automaton:




and consider the zone $Z1 \stackrel{\text{def}}{=} \langle L_1, \varphi \rangle$ s.t

$$\varphi \stackrel{\text{def}}{=} (x \geq 2) \wedge (x \leq 4) \wedge (y \geq 4) \wedge (y \leq 5) \wedge (y - x \leq 2).$$

Compute $succ(\varphi, e)$, displaying the process in a cartesian graph.

[SCORING: [0...100], 100 pts for a correct answer, -33 pts for a wrong answer, 0pts if unanswered..]