Course "Formal Methods"
TEST

Roberto Sebastiani
DISI, Università di Trento, Italy

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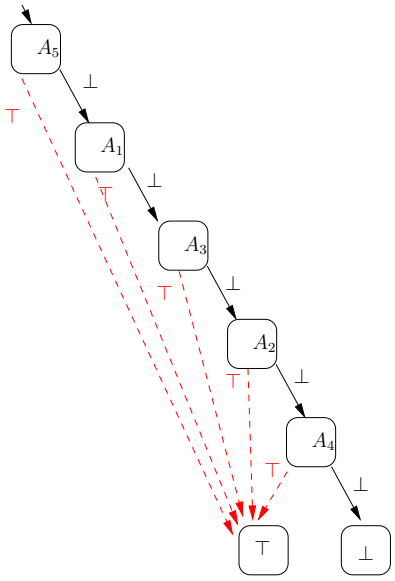
769857918

Name (please print):

Surname (please print):

1

Given the following OBDD, with the ordering $\{\ A_5,\ \ A_1,\ \ A_3,\ \ A_2,\ \ A_4\}$,



for each of the following Boolean formulas, say whether the OBDD represents it or not.

(a) $(\neg A_5 \to (\neg A_1 \to (\neg A_3 \to (\neg A_2 \to \ \ A_4))))$

(b) $(\ \ A_2 \vee \ \ A_1 \vee \ \ A_5 \vee \ \ A_3 \vee \ \ A_4)$

(c) $(\ \ A_3 \wedge \ \ A_5 \wedge \ \ A_4 \wedge \ \ A_1 \wedge \ \ A_2)$

(d) $(\ \ A_5 \to (\ \ A_1 \to (\ \ A_3 \to (\ \ A_2 \to \neg A_4))))$

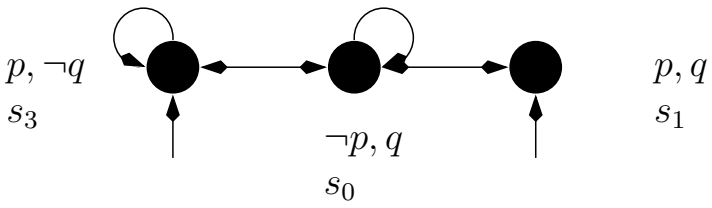
[SCORING [0...100]:

- +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 LTL.

(*a*) $M \models \mathbf{GF}p$

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

(*c*) $M \models p\mathbf{U}q$

(*d*) $M \models (\mathbf{GF}\neg p \wedge \mathbf{GF}\neg q) \rightarrow p$

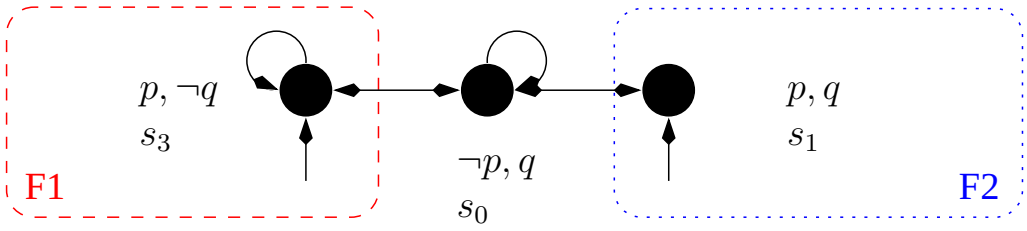
[SCORING [0...100]:

- +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 LTL.

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

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

(c) $M \models p\mathbf{U}q$

(d) $M \models (\mathbf{GF}\neg p \wedge \mathbf{GF}\neg q) \rightarrow p$

[SCORING [0...100]:

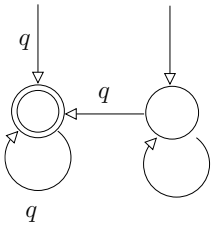
- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

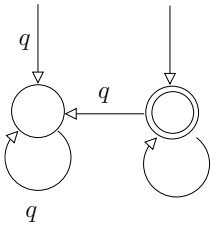
4

For each of the following fact regarding Buchi automata, say if it true or false.

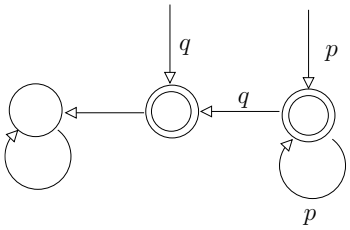
(a) The following BA represents $\mathbf{FG}q$:



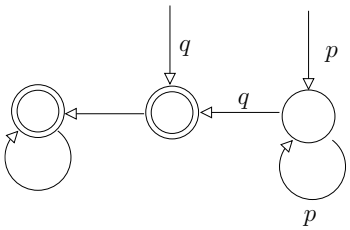
(b) The following BA represents $\mathbf{FG}q$:



(c) The following BA represents $p\mathbf{U}q$:



(d) The following BA represents $p\mathbf{U}q$:



[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) := FALSE;
  init(v2) := TRUE;
  init(v3) := FALSE;
TRANS
  (next(v1) <-> v2) &
  (next(v2) <-> v3) &
  (next(v3) <-> v1)
```

M':

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

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

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

[SCORING [0...100]:

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

]

6

Consider the following piece of a much bigger formula, which has been fed to a CDCL SAT solver:

$$
\begin{aligned}
c_1 &: \neg A_9 \vee \quad A_{12} \vee \neg A_1 \\
c_2 &: \quad A_9 \vee \neg A_7 \vee \neg A_3 \\
c_3 &: \neg A_{11} \vee \quad A_5 \vee \quad A_2 \\
c_4 &: \neg A_{10} \vee \neg A_{12} \vee \quad A_{11} \\
c_5 &: \neg A_{11} \vee \quad A_6 \vee \quad A_4 \\
c_6 &: \neg A_9 \vee \quad A_{10} \vee \neg A_1 \\
c_7 &: \quad A_9 \vee \quad A_8 \vee \neg A_3 \\
c_8 &: \neg A_5 \vee \neg A_6 \\
c_9 &: \quad A_7 \vee \neg A_8 \vee \quad A_{13} \\
&\ldots
\end{aligned}
$$

Suppose the solver has decided, in order, the following literals (possibly interleaved by others not occurring in the above clauses):

$\{..., \quad A_1, ...\neg A_2, ...\neg A_4, ... \quad A_3, ...\neg A_{13}, ..., \quad A_9\}$

(a) List the sequence of unit-propagations following after the last decision, each literal tagged (in square brackets) by its antecedent clause

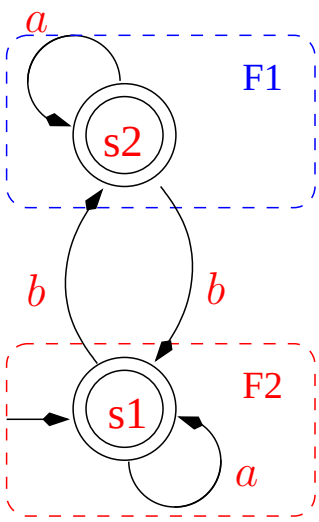
(b) Derive the conflict clause via conflict analysis by means of the 1st-UIP technique

(c) Using the 1st-UIP backjumping strategy, update the list of literals above after the backjumping step and the unit-propagation of the UIP

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

7

Given the following generalized Büchi automaton $A \stackrel{\text{def}}{=} \langle Q, \Sigma, \delta, I, FT \rangle$, $\{a, b\}$ being labels, with two sets of accepting states $FT \stackrel{\text{def}}{=} \{F1, F2\}$ s.t. $F1 \stackrel{\text{def}}{=} \{s2\}, F2 \stackrel{\text{def}}{=} \{s1\}$:



convert it into an equivalent plain Büchi automaton.

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

8

Consider the following LTL formula:

$$\varphi \stackrel{\text{def}}{=} (\mathbf{F}r) \rightarrow (p\mathbf{U}q)$$

and the following three states of the construction of the tableau T_φ of φ:

$S_1 : \langle \ q, \ \ p, \neg\mathbf{X}(p\mathbf{U}q), \ \ r, \ \ \mathbf{XF}r\rangle$

$S_2 : \langle \neg q, \ \ p, \ \ \mathbf{X}(p\mathbf{U}q), \ \ r, \neg\mathbf{XF}r\rangle$

$S_3 : \langle \ q, \neg p, \neg\mathbf{X}(p\mathbf{U}q), \neg r, \neg\mathbf{XF}r\rangle$

For each of the following statements, say if it is true or false.

(*a*) S_2 is a successor of S_1 in T_φ.
(*b*) S_3 is a successor of S_2 in T_φ.
(*c*) S_3 is an initial state of T_φ.
(*d*) S_2 is an accepting state of T_φ.

[SCORING [0...100]:

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

]

[SCORING: [0...100], 25 pts for each correct answer. No penalties for wrong answers.]

9

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

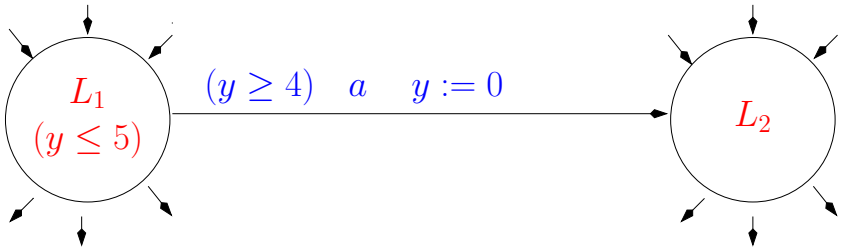
```
MODULE main
VAR x : boolean; y : boolean;
INIT (!x & !y)
TRANS (next(x) <-> !x) & (next(y) <-> (x<->y))

LTLSPEC G (x<->y)
```

1. Write a Boolean formula corresponding to the Bounded Model Checking problem with $k = 2$.
2. Is there a solution? If yes, find the corresponding execution.
3. From the answers of questions 1) and 2) we can deduce
   (*a*) that $M \models \varphi$.
   (*b*) that $M \not\models \varphi$.
   (*c*) nothing.

[SCORING: [0...100], 50 pts for question 1, 25pts each for questions 2, 3. 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

$$\varphi \stackrel{\text{def}}{=} (x \geq 0) \wedge (x \leq 2) \wedge (y \geq 1) \wedge (y \leq 3) \wedge (y - x \leq 2).$$

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..]