Exam in *Principles of Model Checking*

Course number 192114100

Prof. Dr. Joost-Pieter Katoen

January 24, 2017, 08:45 – 11:15

Family name: ______________________________

First name: ______________________________

Student number: ______________________________

Please note the following hints:

- Keep your student id card ready.
- The only allowed materials are
  - a copy of the book,
  - a copy of the lecture slides.
  - a dictionary.

  Other materials (e.g., exercises, solutions, handwritten notes) are not admitted.
- Write your name and student number on every sheet.
- Write with blue or black ink; do not use a pencil.
- Any attempt at deception leads to failure for this exam, even if it is detected only later.
- The editing time is **150 minutes**.

Question	Possible	Received
1	10	
2	10	
3	10	
4	10	
5	10	
Total	50	
Grade		

Question 1 (10 points)

Prove or disprove the following statements:

(a) The complement of a safety property is a liveness property.

(b) The complement of a safety property is again a safety property.

(c) The complement of a liveness property is a safety property.

(d) The complement of a liveness property is again a liveness property.

Question 2 (10 points)

(a) Prove or disprove that the following two LTL formula are equivalent: $\Diamond \bigcirc a \equiv \bigcirc \Diamond a$.

(b) Show there is **no** equivalent LTL formula for the CTL formula $\forall\Diamond\forall\bigcirc a$.

(c) Assume we know that $\forall\bigcirc\forall\Diamond a \equiv \bigcirc\Diamond a$ which means that for all transition systems TS:

$$TS \models_{CTL} \forall\bigcirc\forall\Diamond a \iff TS \models_{LTL} \bigcirc\Diamond a\ .$$

Based on this assumption and the results above argue whether the two CTL formulas $\forall\Diamond\forall\bigcirc a$ and $\forall\bigcirc\forall\Diamond a$ are equivalent.

Question 3

(10 points)

Let $\psi = a \mathsf{W} b$ and $AP = \{a, b\}$.

(a) Transform ψ into an equivalent basic LTL-formula. The basic LTL syntax is given by the following context free grammar:

$$\varphi ::= \mathsf{true} \mid a \mid \varphi_1 \wedge \varphi_2 \mid \neg\varphi \mid \bigcirc \varphi \mid \varphi_1 \mathsf{U} \varphi_2$$

(b) Compute all elementary sets with respect to $closure(\psi)$
Hint: There are 8 elementary sets.

(c) Use the algorithm from the lecture to construct the GNBA $\mathcal{G}_\psi$ with $\mathcal{L}_\omega(\mathcal{G}_\psi) = Words(\psi)$. Therefore

- define its set of initial states and its acceptance component.
- for each elementary set B, define $\delta(B, B \cap AP)$
  Hint: A transition table suffices, you do not have to draw the automaton.

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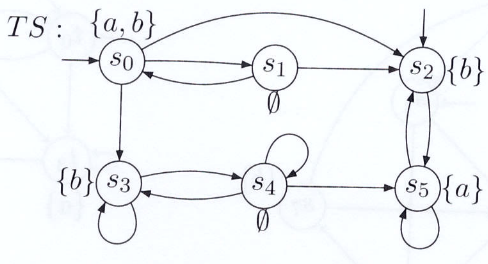
Question 4

(10 points)

Compute $Sat_{sfair}(\Phi)$ for the CTL state-formula Φ and the strong CTL fairness assumption *sfair*:

$$\Phi = \exists\Box\,\forall\Box\,\neg a$$
$$sfair = \Box\Diamond a \rightarrow \Box\Diamond\exists(\neg a)\,\mathsf{U}\,(\forall\bigcirc\, b)$$

where TS over $AP = \{a, b\}$ is given by:



Therefore

(a) Determine $Sat(\exists(\neg a)\,\mathsf{U}\,(\forall\bigcirc\, b))$ (without fairness).

(b) Determine $Sat_{sfair}(\exists\Box\,\text{true})$. Elaborate the steps of the procedure.

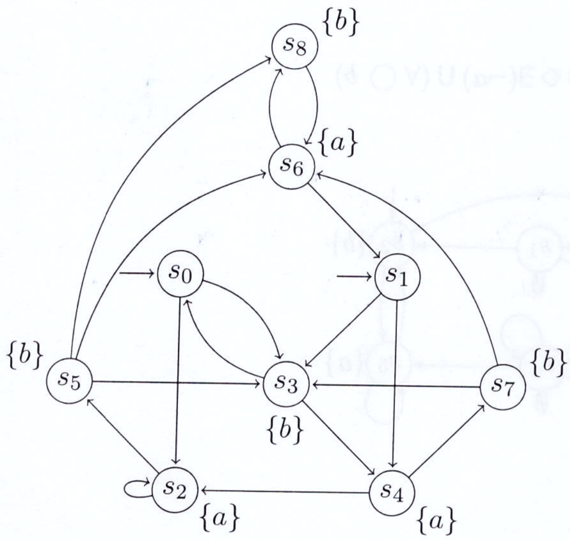
(c) Determine $Sat_{sfair}(\Phi)$. Elaborate the steps of the procedure.

Question 5

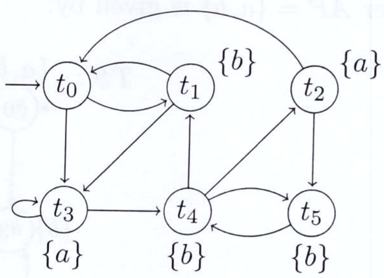
(10 points)

Consider the three transition systems over $AP = \{a, b\}$:

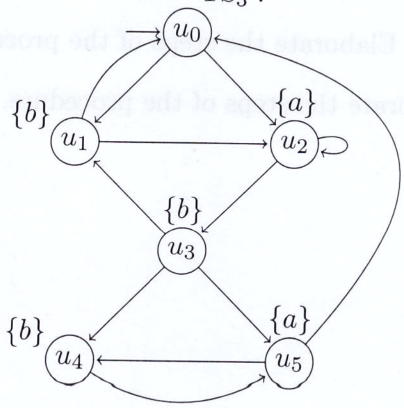
TS_1 :



TS_2 :



TS_3 :



(a) Decide whether $TS_1 \sim TS_2$. In case the systems are bisimiliar provide a bisimulation relation, otherwise give a distinguishing CTL formula.

(b) Decide whether $TS_1 \sim TS_3$. In case the systems are bisimiliar provide a bisimulation relation, otherwise give a distinguishing CTL formula.

(c) Based on your answers to questions a) and b), give an argument whether $TS_2 \sim TS_3$.