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Introduction to Model Checking (Summer Term 2018)

— Exercise Sheet 11 (due 16th July) —

General Remarks

- The exercises are to be solved in groups of *three* students.
- You may hand in your solutions for the exercises just before the exercise class starts at 12:15 or by dropping them into the "Introduction to Model Checking" box at our chair *before 12:00*. Do *not* hand in your solutions via L2P or via e-mail.
- If a task asks you to justify your answer, an explanation of your reasoning is sufficient. If you are required to prove a statement, you need to give a *formal* proof.
- This is the last exercise sheet. If you have gained at least **90.5 points in total** (40% of 226), you are admitted to the exam. If you have gained at least **59 bonus points** (70% of 84), you get a 0.3 bonus on your grade for the exam.

Exercise 1★ (2 + 3 Points)

(a) Give a transition system TS without terminal states that contains two states s_1 and s_2 such that $s_1 \not\equiv_{\text{LTL}} s_2$ and there is *no* LTL formula φ with $s_2 \models \varphi$ and $s_1 \not\models \varphi$.

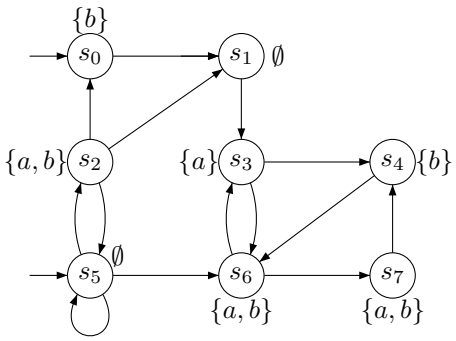
(b) Let TS_1 and TS_2 be transition systems over AP without terminal states such that $\text{TS}_1 \not\equiv_{\text{CTL}} \text{TS}_2$. Prove or disprove: there exists a CTL formula Φ over AP such that $\text{TS}_1 \models \Phi$ and $\text{TS}_2 \not\models \Phi$.

Exercise 2 (5 Points)

Consider the CTL*-formula (with derived operators) over $\text{AP} = \{a, b\}$

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

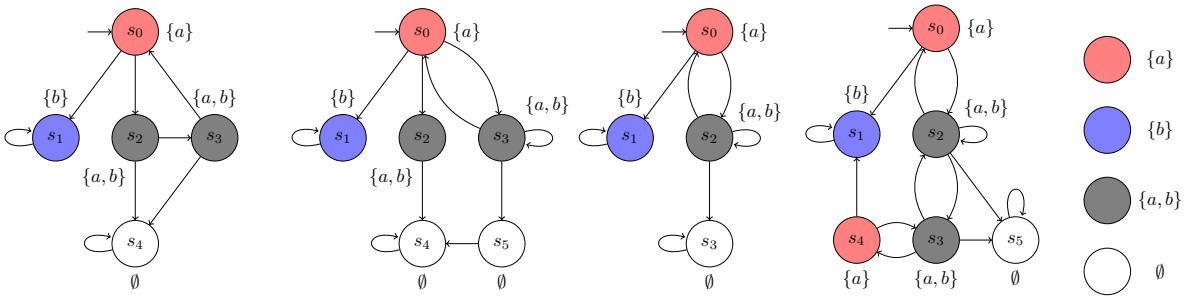
and the transition system TS outlined below:



Apply the CTL* Model Checking Algorithm to compute $\mathit{Sat}(\Phi)$ and decide whether $\text{TS} \models \Phi$.
Hint: You may infer the satisfaction sets for LTL formulas directly.

Exercise 3 (2+2 Points)

Consider the following transition systems $\mathrm{TS}_1, ..., \mathrm{TS}_4$.



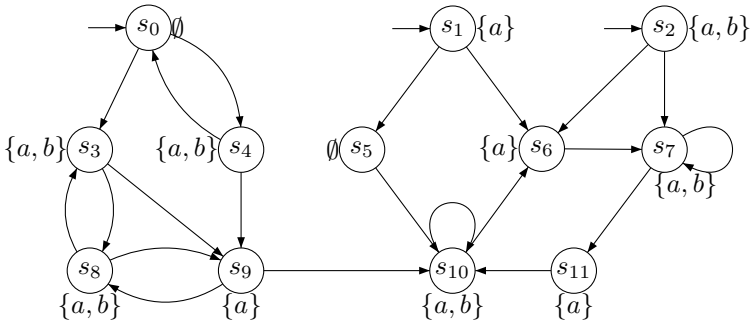
(a) TS_1 (b) TS_2 (c) TS_3 (d) TS_4 (e) Legend

(a) Which transition systems are trace equivalent? Justify your answers by either providing the set of traces or a counterexample trace.

(b) Which transition systems are bisimulation equivalent? Justify your answers by either providing a bisimulation relation or a CTL formula that distinguishes the considered transition systems.

Exercise 4 (3+3 Points)

Consider the transition system TS over $\mathrm{AP} = \{a, b\}$ outlined below:



(a) Determine the bisimulation equivalence $\sim_{\mathrm{TS}}$ and depict the bisimulation quotient system $\mathrm{TS}/\sim$.

(b) For each bisimulation equivalence class C, provide a CTL formula Φ_C that holds only in the states in C.