Technische Universität München (I7) **Summer Semester 2020**
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Model Checking – Exercise sheet 4

Exercise 4.1

Using the *Compare* feature in Spot (`https://spot.lrde.epita.fr/app`) give an LTL formula equivalent to

(a) $p \mathbf{R} q$, which does not contain $\neg$ but may contain $\mathbf{U}, \mathbf{G}$ or $\mathbf{F}$.

(b) $(\mathbf{G}p)\ \mathbf{U}\ q$ which does not contain $\mathbf{U}$.

(c) $(\mathbf{F}p)\ \mathbf{U}\ q$, which does not contain $\mathbf{U}$.

Exercise 4.2

Think of a way to use Spot to check if a word α satisfies an LTL formula ϕ. Check if the word $\{q\}\emptyset\{s\}\emptyset\{p\}^\omega$ satisfies $\mathbf{G}\neg q \vee \mathbf{F}(q \wedge (\neg p\ \mathbf{W}\ s))$.

Exercise 4.3

Challenge: what is the largest LTL formula you can come up with using only one atomic proposition p and without using the $\mathbf{X}$ operator, which Spot is unable to simplify?

Exercise 4.4

Given the following Kripke structures and LTL formulae, answer the following questions

(a) Which of $\mathcal{K}_1, \mathcal{K}_2$ and $\mathcal{K}_3$ satisfy $\phi = \mathbf{G}(\mathbf{X}q \to p)$?

(b) Give an LTL formula which exactly characterizes $\mathcal{K}_3$, i.e. both the formula and the Kripke structure accept exactly the same words.

Exercise 4.5

Let $AP = \{p, q\}$ and let $\Sigma = 2^{AP}$. Give Büchi automata recognizing the ω-languages over Σ defined by the following LTL formulas:

(a) $\mathbf{XG}\neg p$

(b) $(\mathbf{GF}p) \to (\mathbf{F}q)$

(c) $p \wedge \neg(\mathbf{XF}p)$

(d) $\mathbf{G}(p\ \mathbf{U}\ (p \to q))$

(e) $\mathbf{F}q \to (\neg q\ \mathbf{U}\ (\neg q \wedge p))$

Exercise 4.6

Given $L = \{\{p\}^m\{q\}^n\emptyset^\omega : m \leq n\}$, show that there is no Büchi automata recognizing L.

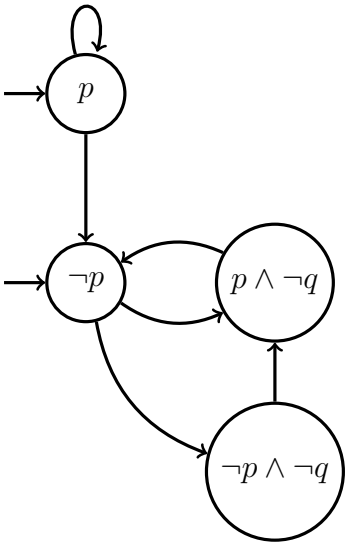

Figure 1: $\mathcal{K}_1$

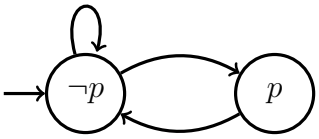

Figure 2: $\mathcal{K}_2$

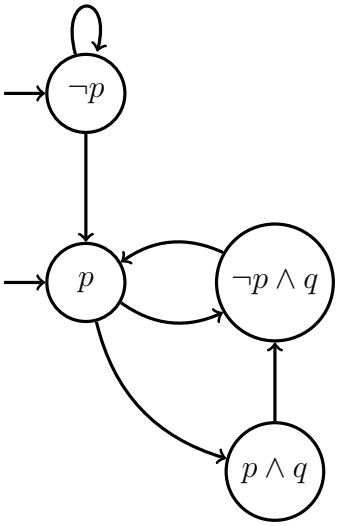

Figure 3: $\mathcal{K}_3$