Software-Modellierung und Verifikation
Informatik 2
Prof. J.-P. Katoen
RWTH Aachen

Henrik Bohnenkamp henrik@cs.rwth-aachen.de

1. Exercise Series “Testing of Reactive Systems 2009”

28 April 2009, 11.45 – 13.15 AH3
Homework due 4 May 2009 (lecture)

About the Homework:

- Achieving 50% of the points in the homework in total are prerequisite to take the exam at the end of the semester (relevant for Master students)
- Homework can be worked on in groups of up to three
- The exercise sheets will be given out in the exercise of week n
- The homework has to be delivered in week n+1 in the lecture
- The solutions will be discussed in the exercise class of week n+2
- The solutions of the exercises will be made available in *non-electronic* form only
- Exceptions from the rules are possible

Not Homework

Exercise 1.1: Determinism

Let $L = (S, Act, \rightarrow)$ be an LTS.

(a) Show that, for $s, s' \in S, \sigma \in Act^*$, with $s \stackrel{\sigma}{\Longrightarrow} s'$,

$$s \text{ is deterministic } \implies s' \text{ is deterministic.}$$

(b) Construct a finite LTS which contains nondeterministic as well as deterministic states, but no deadlock state.

Exercise 1.2:

Recall from automata theory that every nondeterministic finite automaton A can be turned into a deterministic finite automaton A' which recognises the same language, *i.e.*, $\mathcal{L}(A) = \mathcal{L}(A')$. Something similar holds also for any finite-state LTS and its trace set. Let $L = (S, Act, \rightarrow)$. We define now an LTS $L' = (S', Act, \rightsquigarrow)$, where

- $S' = 2^S$, the powerset of S

Find the latest exercise sheets at `http://www-i2.informatik.rwth-aachen.de/i2/testing09`

- $\rightsquigarrow \subseteq 2^S \times Act \times 2^S$ is the least relation fulfiling the following rule:

$$\frac{\underline{\mathcal{S}\ \textbf{after}\ a} = \mathcal{S}' \neq \emptyset}{\mathcal{S} \stackrel{a}{\rightsquigarrow} \mathcal{S}'}$$

  for all $\mathcal{S} \subseteq S$ and $a \in Act$.

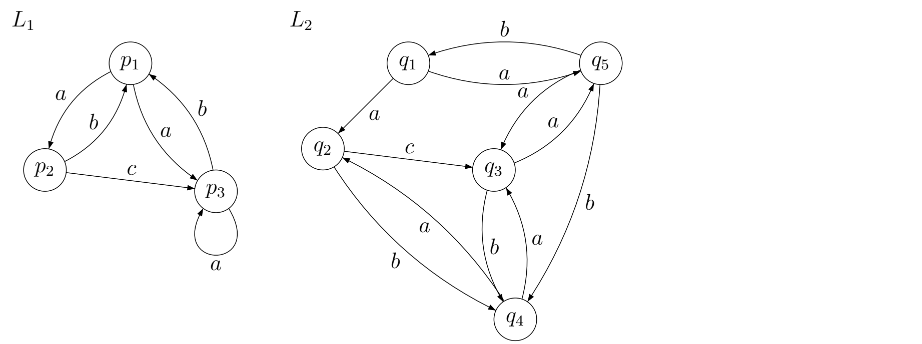
Now show:

(a) L' is deterministic

(b) for every $s \in S$: $traces(s) \subseteq traces(\{s\})$ (by $traces(\{s\})$ we denote the set of traces of state $\{s\}$ of LTS L').

Exercise 1.3:

Given LTS L_1 and L_2:



Let $S = \{p_1, \ldots, p_3, q_1, \ldots, q_5\}$. Show that $p_1 \sim_B q_1$, *i.e.*, find a bisimulation relation $R \subseteq S \times S$ with $p_1 R q_1$.

Exercise 1.4: Infinite Processes

Consider the following process definitions:

$$X = b.STOP \|_{\emptyset} a.X$$

Start deriving the underlying LTS of process X. Derive at least the processes $p \in \underline{X\ \textbf{after}\ a^3}$. What can you notice? When will state space generation end?

Homework

Exercise 1.5: Nondeterminism **(2 Points)**

Following Definition 1.2.8 in the script is a second definition of non-determinism. Argue (if not prove) why these two definitions are equivalent.

Exercise 1.6: Derivation of processes **(4+2 Points)**

Consider Process $P = X \|_{\{a\}} (Y \|_{\emptyset} Z)$ (Example 1.4.3 in the script) with

$$\begin{aligned} X &\hat{=} a.X \\ Y &\hat{=} a.b.Y \\ Z &\hat{=} a.c.Z \end{aligned}$$

Derive formally, similarly to Example 1.4.2 in the script, the two transitions going out from P, using the 7 SOS rules.

Exercise 1.7: Trace equivalence and bisimulation **(2+4+4 Points)**

We define the following processes ($Act = \{a, b, c\}$):

$$\begin{aligned} P_1 &\hat{=} a.P_2 + a.c.P_3 \\ P_2 &\hat{=} a.P_3 + b.P_3 \\ P_3 &\hat{=} a.P_1 \\ Q_1 &\hat{=} a.(a.Q_2 + b.Q_2 + c.Q_2) \\ Q_2 &\hat{=} a.Q_1 \end{aligned}$$

Find out, whether P_1 and Q_1 are trace equivalent and/or bisimilar. If not, why not?

Exercise 1.8: Processes and Bisimulation **(3+4 Points)**

Given the following process definitions.

$$\begin{aligned} X_1 &\hat{=} b.a.X_1 \\ X_2 &\hat{=} c.a.X_2 \\ Y &\hat{=} X_1 \|_a X_2 \end{aligned}$$

(a) Derive the LTS of Y.

(b) Define a process $p \in \mathbb{P}$ without containing any parallel operators such that the LTS underlying p is bisimilar to the one underlying Y. Give a reason why your solution *is* bisimilar.