

Exercises to the lecture  
Concurrency Theory  
Sheet 2

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Delivery until 06.05.2014 at 12h

**Exercise 2.1** (Locks)

We define a simple lock library:

$$\begin{array}{ll} \mathbf{lock} := & \mathbf{unlock} := \\ \mathbf{atomic} ( & \mathbf{atomic} ( \\ \quad t = [l]; & \quad t = [l]; \\ \quad \mathbf{assume}(t = 0); & \quad \mathbf{assume}(t = 1); \\ \quad [l] = 1 & \quad [l] = 0 \\ ) & ) \end{array}$$

Let  $I$  be a formula.

- a) Define a resource invariant  $R$  so that the following hold:

$$R \vdash \{\mathbf{emp}\} \mathbf{lock} \{I\} \quad \text{and} \quad R \vdash \{I\} \mathbf{unlock} \{\mathbf{emp}\}$$

- b) Prove the soundness of the rule

$$\frac{R \vdash \{P * I\} C \{Q * I\}}{R \vdash \{P\} \mathbf{lock}; C; \mathbf{unlock} \{Q\}}$$

**Exercise 2.2** (Locks)

Consider the following programs  $C_i$  for  $i \in \mathbb{N}$ :

$$\begin{array}{l} \mathbf{local} \ x \ \mathbf{in} \\ \quad x = [a]; \\ \quad [y_i] = 1 \\ \quad [a] = x + 1; \end{array} \quad \text{with} \quad \frac{J \vdash \{P\} C \{Q\} \text{ and } x \notin \text{fv}(J, P, Q)}{J \vdash \{P\} \mathbf{local} \ x \ \mathbf{in} \ C \{Q\}}$$

- a) Assume that  $a \mapsto 0$  initially holds. What are the possible values of  $[a]$  when the program  $C_1 \parallel C_2$  terminates? Add locks to  $C_i$  so that  $a \mapsto 2$  holds at the end.
- b) Prove for your new programs  $C'_i$ :

$$\{a \mapsto 0 * y_1 \mapsto 0 * y_2 \mapsto 0\} C'_1 \parallel C'_2 \{a \mapsto 2 * y_1 \mapsto 1 * y_2 \mapsto 1\}$$

*Hint:* you have to use fractional permissions.

**Exercise 2.3** (Soundness of Rules)

a) Prove the soundness of the FREE rule:

$$\overline{J \vdash \{E \mapsto -\} \mathbf{dispose}(E) \{\mathbf{emp}\}}$$

b) Prove the soundness of the SHARE rule:

$$\frac{J * R \vdash \{P\} C \{Q\}}{J \vdash \{P * R\} C \{R * R\}}$$

*Hint:* You have to show Lemma 14 in the lecture notes.

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