Universität Leipzig
Institut für Informatik
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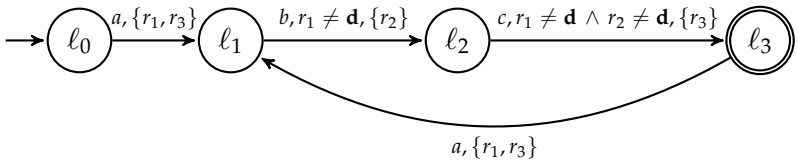
Exercises

Verification for Infinite-State Systems

Exercise Sheet 4 (for 12.11.2026)

Exercise 4.1

Consider the register automaton depicted below:



For the following strings, decide whether they can form valid abstract transition relations in its data-abstract automaton. If yes, give a/the corresponding missing information (the missing location and/or the missing abstract data value); if not, give the key argument why not.

(a) $(\ell_2, \{\{r_1\}, \{r_2\}, \{r_3\}_\perp\}) \xrightarrow{c} (\ell_3, ?)$

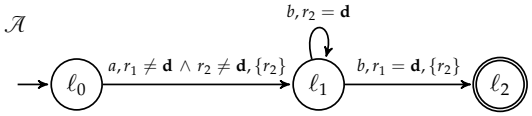
(b) $(\ell_2, ?) \xrightarrow{c} (\ell_3, \{\{r_1, r_3\}, \{r_2\}\})$

(c) $(\ell_3, ?\}) \xrightarrow{a} (\ell_1, \{\{r_1, r_3\}, \{r_2\})$

(d) $(?, ?) \xrightarrow{a} (\ell_1, \{\{r_1, r_2, r_3\}\})$

Exercise 4.2

For the register automaton $\mathcal{A}$ depicted below, construct the corresponding data abstract automaton $\mathcal{B}_\mathcal{A}$. You may omit states that cannot be reached.



Let Σ be a finite alphabet. Given a data word w of the form $(a_1, d_1) \dots (a_n, d_n)$ over Σ, we use $\pi_\Sigma(w)$ to denote the word $a_1 \dots a_n$ obtained from w by removing all data. Given a data language L over Σ, we use $\pi_\Sigma(L)$ to denote the language $\{\pi_\Sigma(w) \mid w \in L\}$.

Exercise 4.3
Prove that for every register automaton $\mathcal{A}$, we have $L(\mathcal{B}_\mathcal{A}) = \pi_\Sigma(L(\mathcal{A}))$, where $\mathcal{B}_\mathcal{A}$ is the data abstract automaton of $\mathcal{A}$.

Exercise 4.4
Let $L \subseteq (\Sigma \times \mathbb{N})^*$ be a data language. Which of the following two statements is correct? Prove your answer!

(a) If L is data regular, then $\pi_\Sigma(L)$ is regular.

(b) If $\pi_\Sigma(L)$ is regular, then L is data regular.

Exercise 4.5
Which of the following data languages is data regular? Prove your answer!

(a) $L_1 = \{(a_1, d_1) \dots (a_{2n}, d_{2n}) \mid a_1 \dots a_{2n}$ is a palindrome, $n \geq 1\}$

(b) $L_2 = \{(a_1, d_1) \dots (a_{2n}, d_{2n}) \mid d_1 \dots d_{2n}$ is a palindrome, $n \geq 1\}$

Exercise 4.6
Prove the correctness of the **NSPACE** algorithm for solving the nonemptiness problem for register automata (cf. Lecture 4). That is, prove that the algorithm answers with "YES" if, and only if, $L(\mathcal{B}_\mathcal{A}) \neq \emptyset$.