

A lower bound for web service composition ¹

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Simulation problem

Problem

- *Input:* DFA $\mathcal{A}_1, \dots, \mathcal{A}_n, \mathcal{B}$
- *Question:* Does $\mathcal{A}_1 \otimes \dots \otimes \mathcal{A}_n$ simulate \mathcal{B} ?

Simulation relation

For $\mathcal{A} = \langle Q_{\mathcal{A}}, \Sigma, \delta_{\mathcal{A}}, q_{\mathcal{A}}^0 \rangle, \mathcal{B} = \langle Q_{\mathcal{B}}, \Sigma, \delta_{\mathcal{B}}, q_{\mathcal{B}}^0 \rangle$:

$\mathcal{B} \leq \mathcal{A}$ if there exists a relation $R \subseteq Q_{\mathcal{B}} \times Q_{\mathcal{A}}$ s.t.

- $(q_{\mathcal{B}}^0, q_{\mathcal{A}}^0) \in R$, and
- for every $(p, q) \in R, a \in \Sigma, p \xrightarrow{a} p'$ there exists q' s.t. $q \xrightarrow{a} q'$ and $(p', q') \in R$.

Equivalently: simulation game.

Result & motivation

Result

EXPTIME lower bound for the simulation problem when the product is **fully asynchronous** (for constant-size alphabet Σ).

Moreover, if the alphabets of the \mathcal{A}_i are disjoint, then the problem is in PTIME.

Motivation

- 1 (de Giacomo et al.'03, '05): EXPTIME upper bound (Roman model, a simplified version of Colombo)
Web service **composition**: given services $\mathcal{A}_1, \dots, \mathcal{A}_n$, is it possible to compose them (find a *delegator*) for obtaining a service \mathcal{B} ?
- 2 **orchestration problem**: find a communication architecture between peers p_1, \dots, p_n with services $\mathcal{A}_1, \dots, \mathcal{A}_n$ such that $\prod_i \mathcal{A}_i$ and \mathcal{B} are bisimilar.

Variants

- 1 automata/product
 - fully asynchronous
 - partial synchronization (Schnoebelen/Laroussinie '00)
 - communicating (finite-) state machines (Roman model, Vianu)
- 2 simulation vs. bisimulation
- 3 arbitrary many copies of each \mathcal{A}_i

Rem.

Here: simplest possible setting (no synchronization).

Lower bound much easier with synchronization.

Proof ideas (1)

Reduction

Given DTM M , word w , is the computation of M on w infinite?

$$\mathcal{A}_i = \langle S_i, \Sigma_i, s_i^0, \delta_i : S_i \times \Sigma_i \rightarrow S_i \rangle, \quad \mathcal{B} = \langle S, \Sigma = \bigcup_i \Sigma_i, s^0, \delta : S \times \Sigma \rightarrow S \rangle$$

Proof

- first, PSPACE lower bound; second, extension to EXPTIME
- classical idea: \mathcal{A}_i controls the i -th tape symbol of a TM, \mathcal{B} controls the head moves (“synchronization”)
- proof with arbitrary alphabets Σ_i , then reduction to constant size

Proof ideas (2)

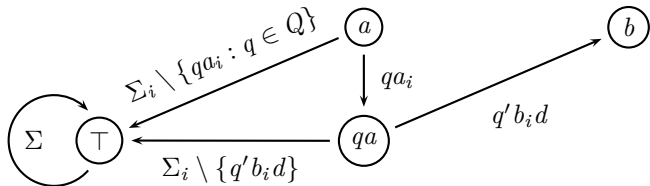


Figure: qa has no outgoing transitions if M has no move

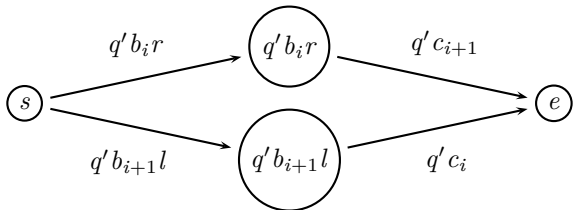


Figure: \mathcal{B} : $s = e = s^0$

Proof ideas (3)

- From PSPACE to EXPTIME: same with alternation (difficulty: existential moves)
- Constant-size alphabet: replace each transition $s \xrightarrow{a_k} s'$ by unary encoded transitions

$$s \xrightarrow{a} \langle s, s', k, 0 \rangle \xrightarrow{\#} \langle s, s', k, 1 \rangle \xrightarrow{\#} \dots \langle s, s', k, k \rangle \xrightarrow{\$} s'$$

- Disjoint alphabets Σ_i in PTIME:
 \mathcal{B} is simulated by $\mathcal{A}_1 \otimes \dots \otimes \mathcal{A}_n$ iff \mathcal{B} is Σ_i -simulated by \mathcal{A}_i , for each i

Open questions

- Complexity of bisimulation?
- Simulation of FSM by product of arbitrary many copies?