Computation of Summaries Using Net Unfoldings

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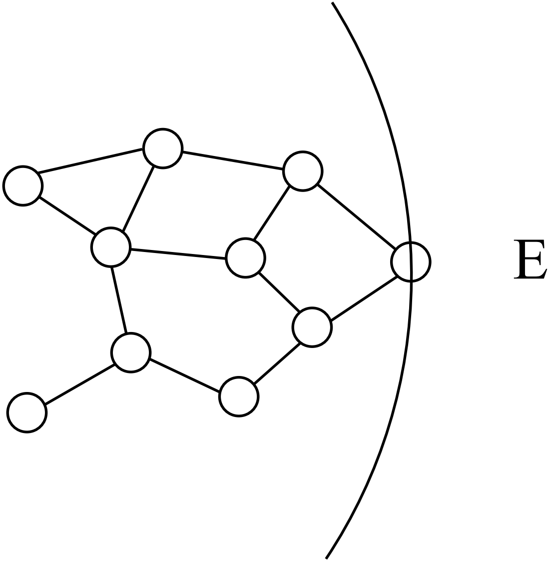
joint work with Javier Esparza and Stefan Schwoon

FSTTCS
December 12-24, 2013

The summary problem

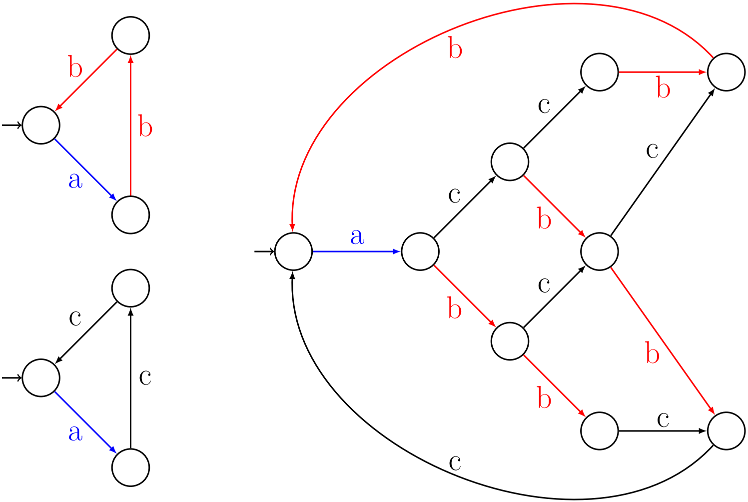


The summary problem

S ——— E

Some definitions

Problem representation: LTSs, parallel composition



The summary problem in terms of LTSs

Summary with interface A_i

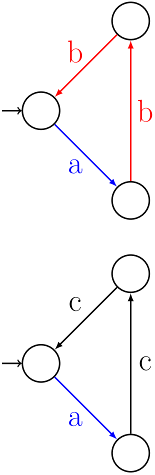
Given $A_1, A_2, \ldots, A_n$, LTSs
Given A_i, distinguished LTS with set of labels Σ_i
Find an LTS S_i such that:

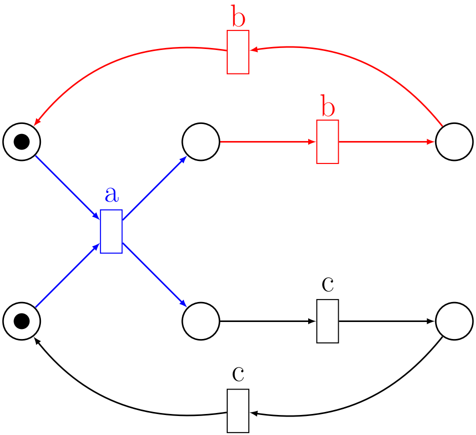
$$S_i \equiv (A_1 || \ldots || A_n) \setminus \overline{\Sigma_i}$$

$||$ parallel composition
$\setminus$ hiding
$\overline{\Sigma}$ complement

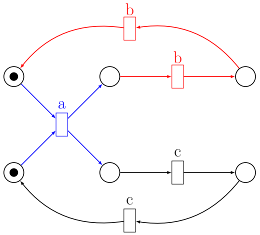
Solution overview

Use concurrency: parallel composition as a Petri net





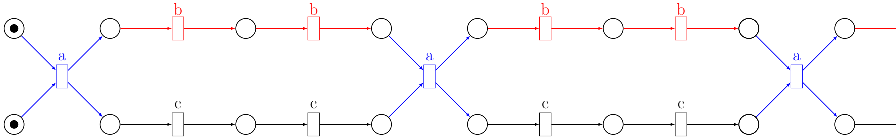
Use concurrency: unfolding



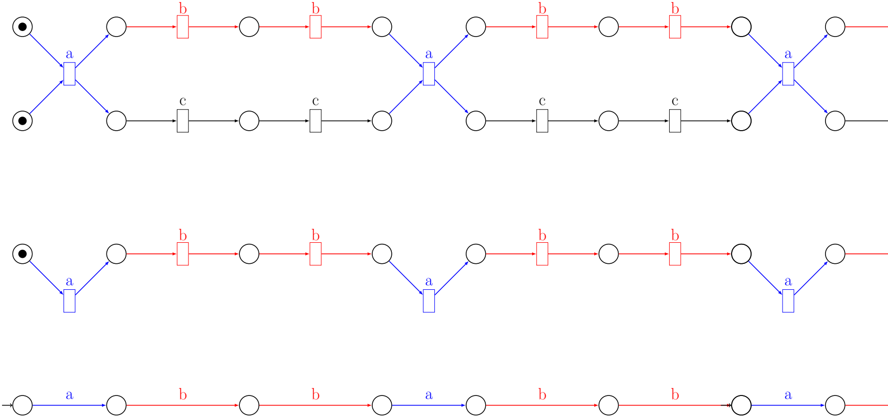
Unfolding algorithm

input: a (safe) Petri net P
output: its unfolding N

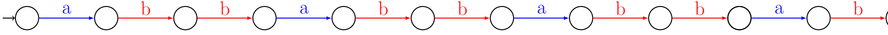
initialize N from the marked places of P
while $Ext(N, P) \neq \emptyset$
  choose $e \in Ext(N, P)$
  extend N with e

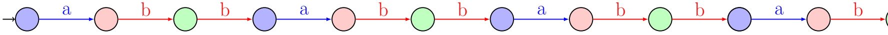


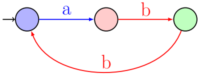
Use concurrency: unfolding and interface projection



Use concurrency: refolding



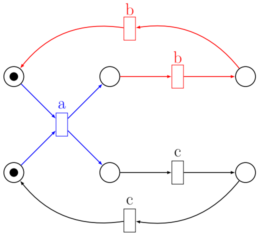


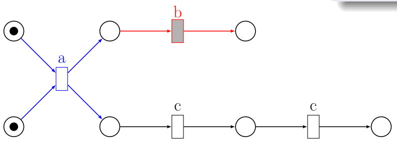


Equivalence classes

Will be defined using information from the unfolding

Use concurrency: cut-off events





Unfolding algorithm

input: a (safe) Petri net P
output: a **prefix** of its unfolding N

initialize N from the marked places of P
initialize co as an empty set
while $Ext(N, P, co) \neq \emptyset$
  choose $e \in Ext(N, P)$
  extend N with e
  if e is cut-off **then** $co \leftarrow co \cup \{e\}$

Goal

- Finite prefix
- Preserves relevant properties

The summary problem in terms of cut-offs

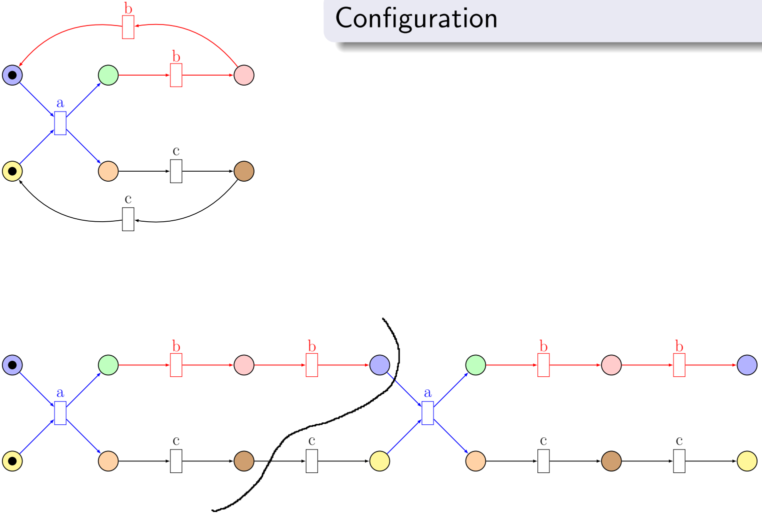
Find a definition of cut-offs and a definition of equivalence relation so that given $A_1, A_2, \ldots, A_n$, given A_i with set of labels Σ_i,

$$S_i = Folding(Interface(Unfolding(A_1 || \ldots || A_n)))$$

is a solution to the summary problem with interface A_i:

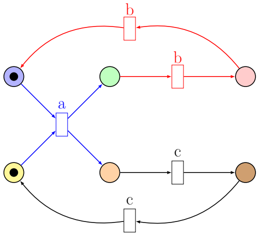
$$S_i \equiv (A_1 || \ldots || A_n) \setminus \overline{\Sigma_i}$$

Equivalence relation



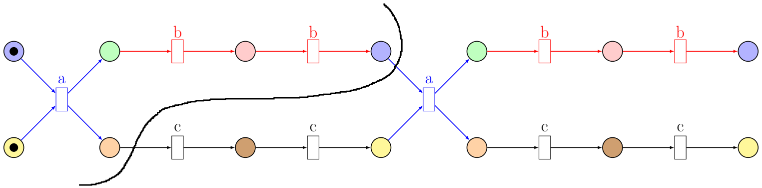
Configuration

Equivalence relation

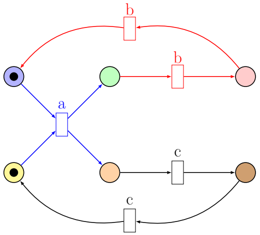


Configuration

Minimal configuration, global state



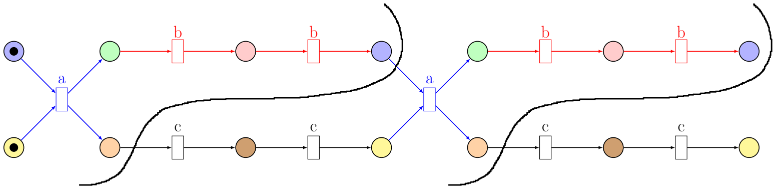
Equivalence relation



Configuration

Minimal configuration, global state

Equivalent places



Cut-off definitions

Cut-off definition for non-divergent systems

Cut-off definition

An event e is cut-off if:

- it is an interface event, and
- there exists an interface event e' in N such that e and e' correspond to the same global state.

Unfolding algorithm

input: a (safe) Petri net P
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initialize N from the marked places of P
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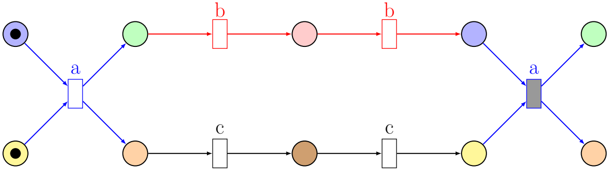

Cut-off definition for non-divergent systems

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An event e is cut-off if:

- it is an interface event, and
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Non-divergent system

Any infinite execution involves an infinite number of transitions from A_i.

Theorem

If $A_1 || \ldots || A_n$ is non-divergent then

- N is finite, and
- $Folding(Interface(N))$ is a solution to the summary problem.

Cut-off definition for divergent systems

Cut-off definition

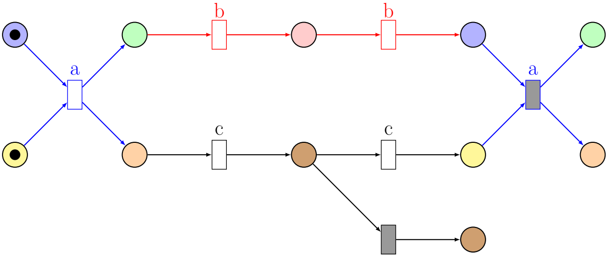
An event e is cut-off if:

- it is an interface event, and
- there exists an interface event e' in N such that e and e' correspond to the same global state.

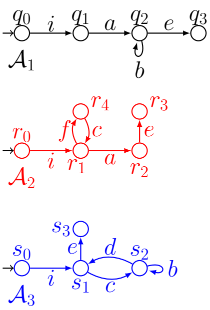
Addition to the cut-off definition

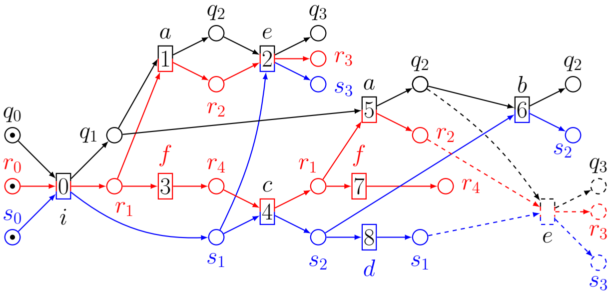
An event e is cut-off if:

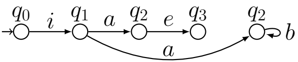
- it is not an interface event, and
- there exists an event $e' < e$ in N such that
  - e and e' correspond to the same global state, and
  - e and e' correspond to the same interface condition.



Counter example







Cut-off candidates

Idea

Non-interface events will not be proper cut-offs but temporary cut-offs:

- stops unfolding as cut-off events,
- can be freed (i.e. stop to be cut-off).

Cut-off definition for divergent systems

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Cut-off definition for divergent systems

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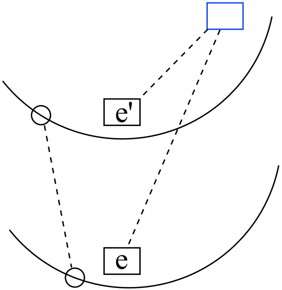

Cut-off candidates

An event e is a cut-off candidate if:

- it is not an interface event, and
- there exists an event $e' \ll e$ in N such that
  - e and e' correspond to the same global state,
  - e and e' correspond to the same interface condition, and
  - if e is concurrent with an interface event e'' (not cut-off), then e' is also concurrent with e''.

Cut-off definition for divergent systems

Cut-offs

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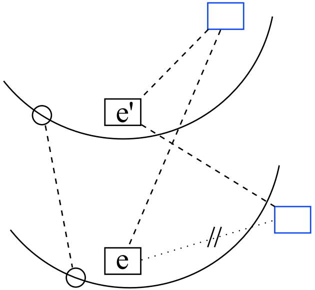

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  - if e is concurrent with an interface event e'' (not cut-off), then e' is also concurrent with e''.

Free candidates

An event e frees a cut-off candidate e' if:

- e' is not a cut-off candidate in N extended with e.

To conclude

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Contributions

- Unfoldings for computing summaries:
  - for traces (experimental analysis in the paper)
  - for weighted traces (in the paper)
  - for divergences (in the paper)
- Notion of cut-off candidates

Future work

- Strong causality
- Other semantics:
  - deadlocks
  - timed traces

Paper with proofs available on arXiv.org arXiv:1310.2143