Soundness in negotiations.

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Highlights of Automata
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Introduction

Negotiations [Desel, Esparza '13]

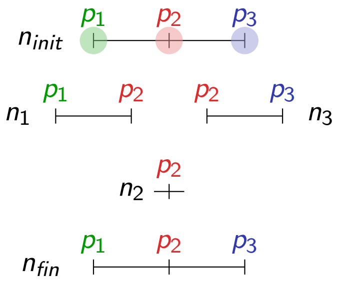
- model multiparty distributed cooperation,
- better complexity than alternative models (Petri Nets),
- embeds natural concepts: soundness, race properties,...

This paper:

- study of different restrictions on the model,
- complexity of deciding soundness, concurrency relationships
- application to workflow analysis for programs

Run of a negotiation

n_{init} initial node, n_{fin} final node.
Here: 3 processes p_1, p_2, p_3 and only one action a.



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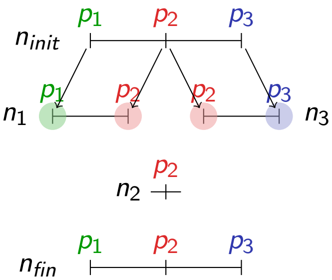

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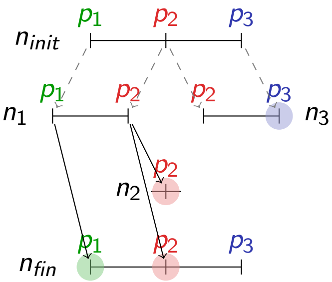

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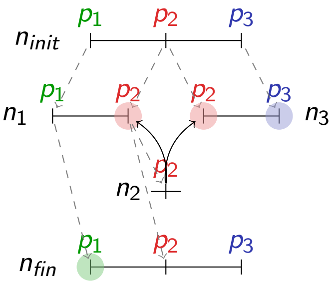

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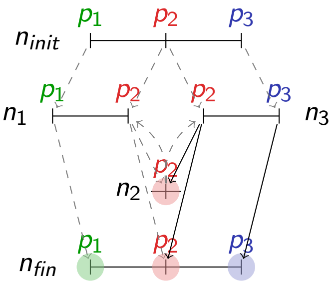

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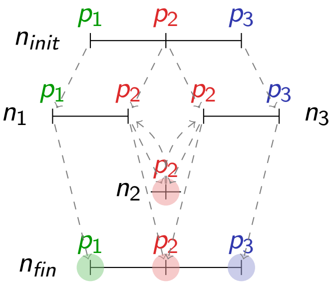

p_2 is non-deterministic, while p_1 and p_3 are deterministic.

The Soundness problem

Soundness property

Soundness:
Every partial run can be completed into an accepting run.
Non-blocking property, witnessing good design.

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Soundness problem PSPACE-complete in general [DE '13].

Subclasses of negotiations

Complexity of the soundness problem for *classes of negotiations*?

Natural Restrictions on negotiations:

- **Deterministic**: All processes are deterministic.
- **Weakly non-deterministic**: All nodes involve at least one deterministic process.
- **Acyclic**: No cycle in the transition graph between nodes.

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Theorem (DE '14)

Deciding soundness is in PTIME for deterministic negotiations.

Results on the complexity of the soundness problem

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Use of the Omitting Theorem: we can decide in PTIME which parts of a negotiation are essential.

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Mildly relaxing acyclicity or weak non-determinism:
$\rightsquigarrow$ Soundness problem becomes coNP-complete.

Det-acyclicity: only deterministic processes are acyclic.
$\rightsquigarrow$ No cycles in runs of weakly ND negociations.

Applications of sound negotiations

Race Property

Race Problem:
INPUT: a sound negotiation $\mathcal{N}$, and two nodes n, m of $\mathcal{N}$.
OUTPUT: can n and m be concurrently enabled ?

- standard question for concurrent systems
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Theorem (EKMW '16)

The race problem is

- *NLOGSPACE-complete for deterministic acyclic negotiations,*
- *in PTIME for deterministic negotiations.*

Workflow Analysis

Application of negotiations: analyze the workflow of programs. We add global variables that can be affected by nodes via operations: $alloc(x)$, $read(x)$, $write(x)$, $dealloc(x)$.

Acyclic deterministic negotiations with variables $\rightsquigarrow$ formalize data-flow problems from the literature [van der Aalst et al, '09]:

- **Well-defined behaviour**: no concurrent operations on the same variable,
- **No redundancy**: allocated variables are used,
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All these properties can be checked in PTIME on data-flows.

Exponential improvement on [van der Aalst et al, '09].

Conclusion

Soundness problem for negotiations:

- PTIME for acyclic weakly non-deterministic
- coNP-complete for mild relaxations

Race problem for sound negotiations:

- NLOGSPACE-complete for deterministic acyclic,
- PTIME for deterministic.

Data-flow analysis:

- modelisation with deterministic acyclic negotiations,
- PTIME algorithms for standard problems on data-flows.

Good Expressivity/Complexity ratio, well-suited for practical use.