Efficient Algorithms for Three Reachability Problems in Safe Petri Nets

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Three reachability problems

- Dead places: finding all places that never have a token
- Dead transitions: finding all transitions that never fire
- Concurrent places: finding all pairs of places that can both have a token simultaneously
- These 3 problems are PSPACE-complete
- We focus on ordinary, safe Petri nets:
  - ordinary: arcs have multiplicity one
  - safe: at most one token per place

Why are these problems interesting?

- Dead places and dead transitions:
  - useful for simplifying complex Petri nets, especially those generated from higher-level formalisms
  - profitable reduction: 20.4% dead places and 37.7% dead transitions
- Concurrent places:
  - crucial role for the decomposition of Petri nets into automata networks [Bouvier et al., Petri Nets 2020]
  - statistically: 67% non-concurrent places

Approach: combination of algorithms

- We propose a combination of several algorithms

1. Exploration of reachable markings
   - PSPACE-complete ⇒ may take too long
⇒ timeout option needed
⇒ exploration may be incomplete
   - incomplete exploration ⇒ unknown values may remain

Approach: combination of algorithms

2. Structural rules:
   - simple theorems to remove unknown values on large nets
   - exploit safeness properties of Petri nets and NUPNs

3. Under and over-approximations:
   - abstraction of the set of reachable markings
   - memory: exponential → linear or quadratic complexity
   - time: exponential → polynomial time complexity

Experimental results

- Two software implementations: in C and Python
- Assessment on a collection of 13,000+ Petri nets from academia, industry, and competitions
  - ≈ 95% of models are completely solved
  - some large models are partially solved (the solution contains unknown values)
- More work needed for the remaining 5%
  - colleagues in Toulouse and Paris have started adapting their tools to address these 3 problems