Synthesis of succinct strategies thanks to ready simulation

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Bruxelles, BELGIQUE

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Motivation

Safety games have a lot of applications:

- scheduler synthesis
- LTL synthesis
- determinization of timed automata

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$\Rightarrow$ using the structure

Outline

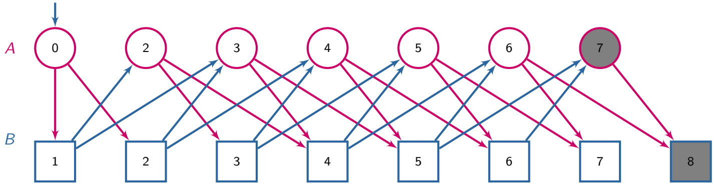
1. Introduction to safety games

2. Structured games

3. Succinct strategies in structured games

4. Efficient construction

Finite turn-based safety games



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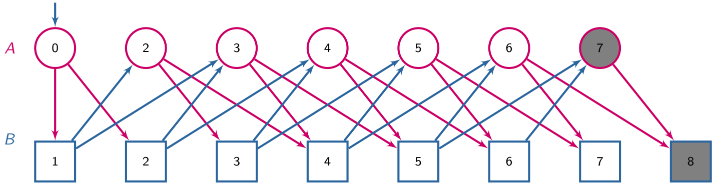

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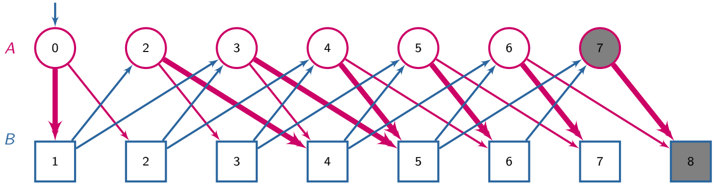

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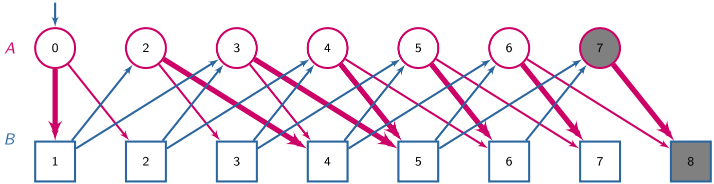

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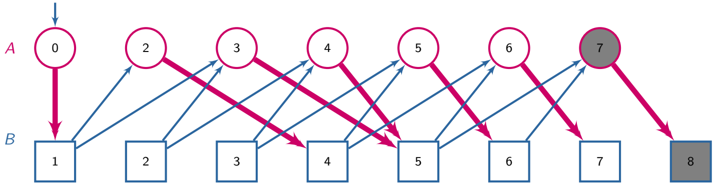

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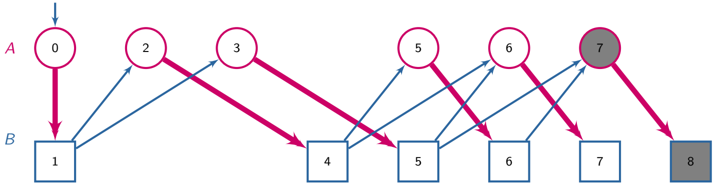

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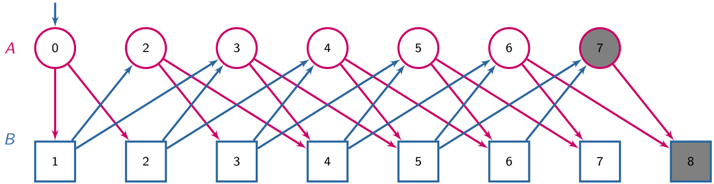

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- Attractors of bad states:
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  - $\mathrm{Attr}_{i+1} = \mathrm{Attr}_i \cup \{v \in V_B | \exists v' \in \mathrm{Attr}_i, v \to v'\}$
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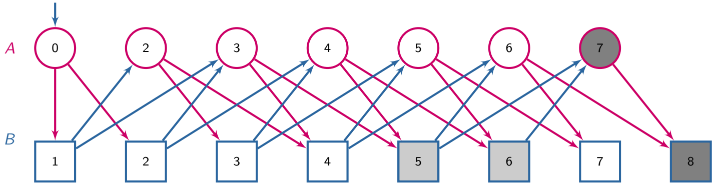

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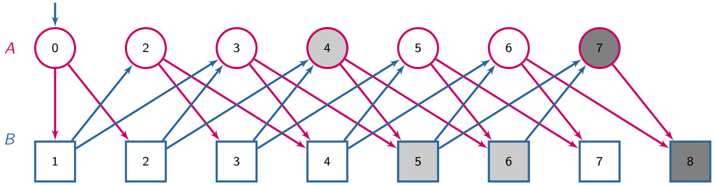

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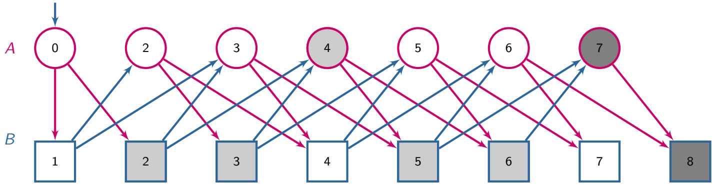

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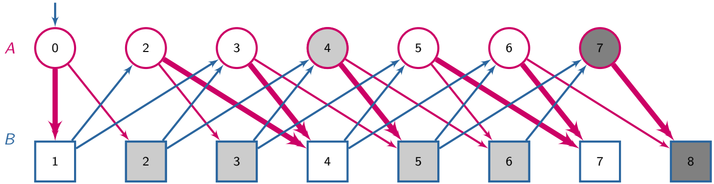

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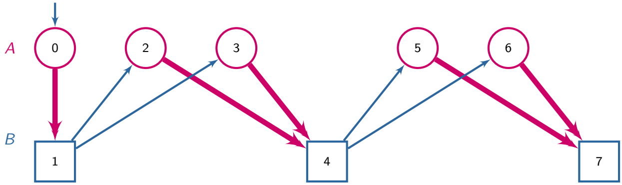

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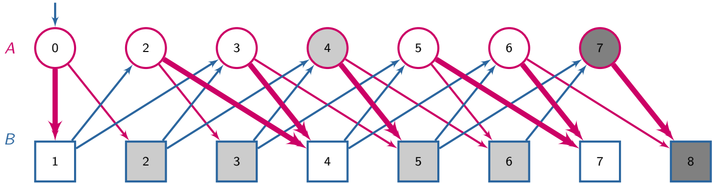
New notion of strategy:

- Strategy of A: $\sigma : V_A \to V_B \cup \{\star\}$ ($\star$ means "don't care")
- G_σ: the arena with only moves of σ (or all the moves if $\sigma(v) = \star$)
- Winning strategy for A: Bad is not reachable in G_σ
- Size of σ: $|\sigma^{-1}(V_B)|$

Back to the running example



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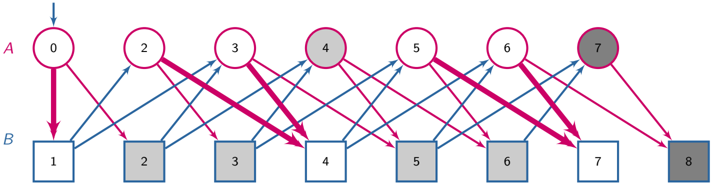

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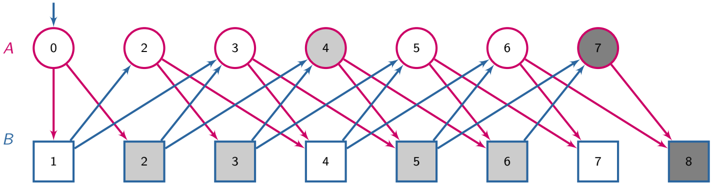

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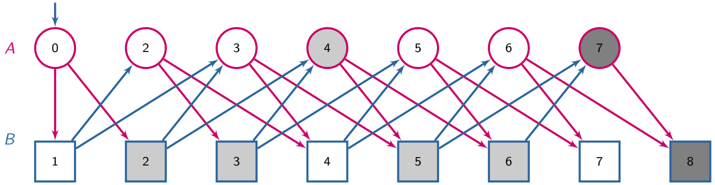

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Deciding whether there exists a winning strategy for A of size k is an NP-Complete problem.

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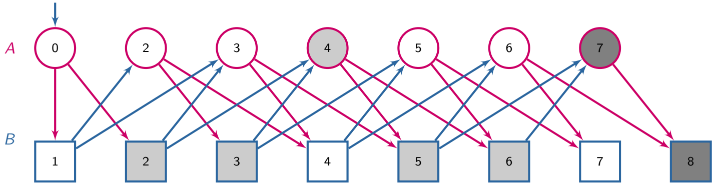

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⇒ A heuristic for structured games

Structured games

simulation relation

For all $v_1 \trianglerighteq v_2$, either $v_1 \in \mathrm{Bad}$, or:

- $v_2 \in \mathrm{Bad} \Rightarrow v_1 \in \mathrm{Bad}$
- $v_2 \rightarrow v_2' \Rightarrow v_1 \rightarrow v_1'$ with $v_1' \trianglerighteq v_2'$

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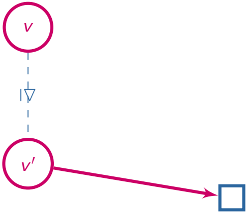

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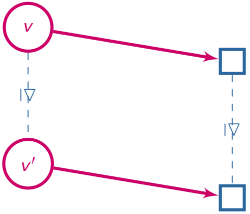

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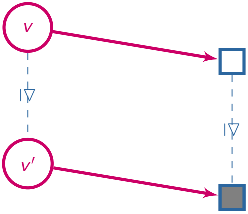

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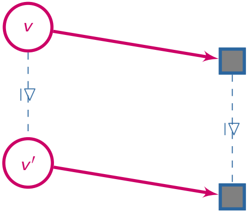

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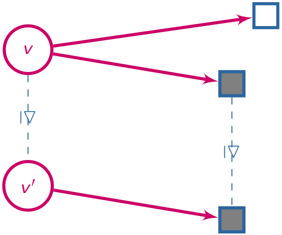

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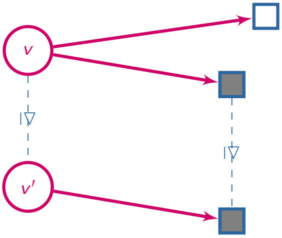

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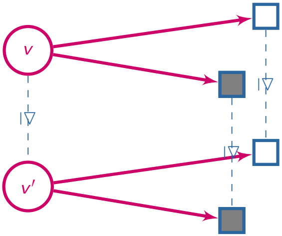

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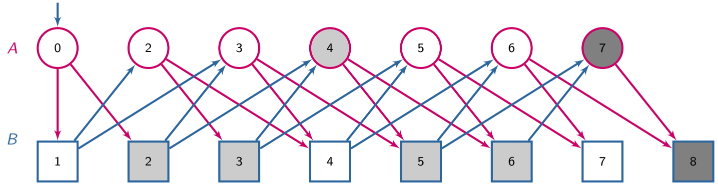

Well-known winning strategy:

always going in a state k of B such that $k \equiv 1 \pmod 3$.

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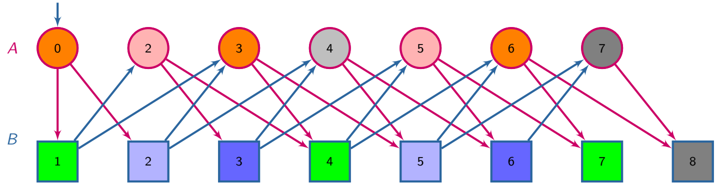

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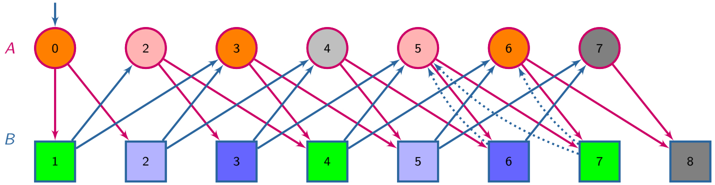

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New notion of winning strategy

- $G_{\sigma,\trianglerighteq}$: if there are $v' \trianglerighteq v$ where σ is defined, only the moves mimicking such moves
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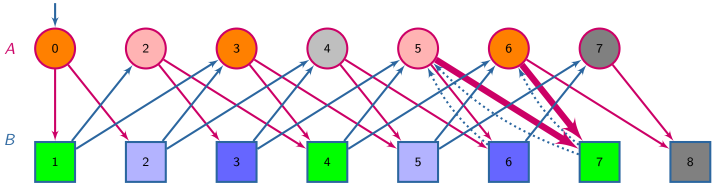

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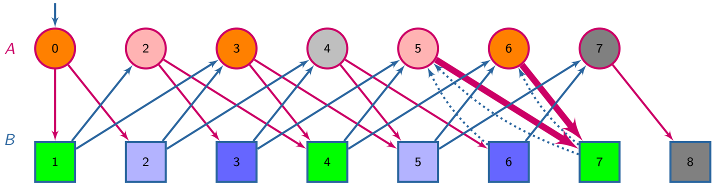

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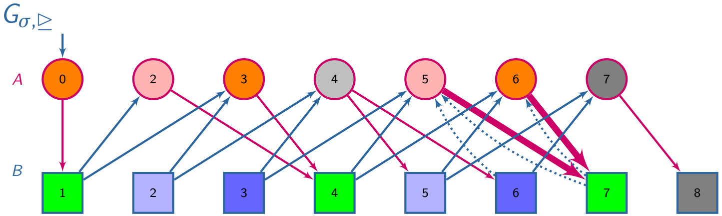

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Let σ be a winning strategy and V' be a maximal antichain on $\mathrm{Reach}(G_\sigma) \cap V_A$, then the strategy $\sigma_{|V'}$ is $\trianglerighteq$-winning.

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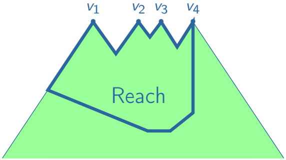

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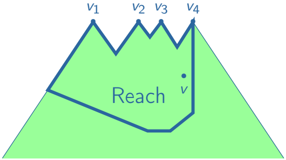

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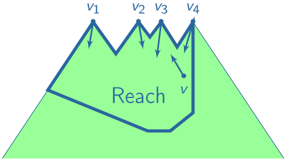

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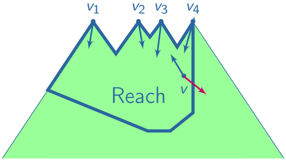

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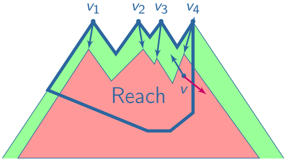

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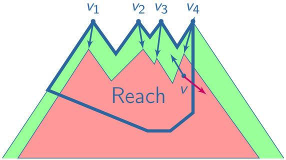

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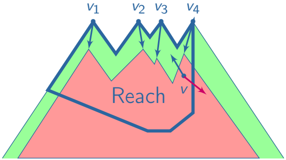

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v_1	...
v_2	...
v_3	...
...	...
...	...
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...	...
v_j	...
...	...
v_{n-1}	...
v_n	...

$\Rightarrow$

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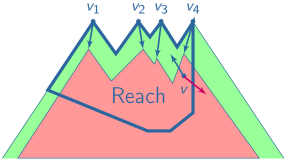

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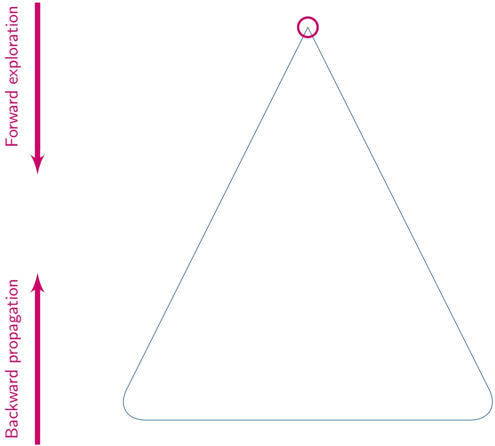
The OTFUR algorithm [CDFLL05] allows to build $\trianglerighteq$-winning succinct strategies.

[CDFLL05] Efficient on-the-fly algorithms for the analysis of timed games.

The OTFUR algorithm [CDFLL05]



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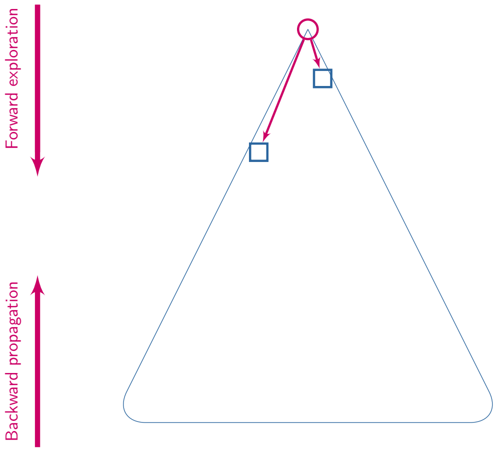

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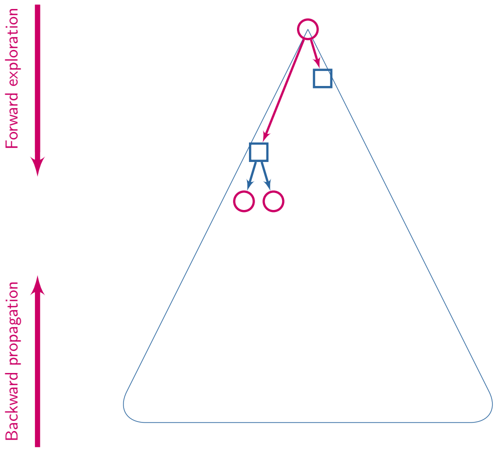

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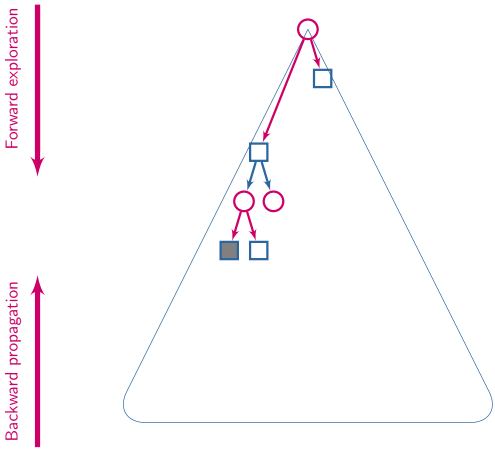

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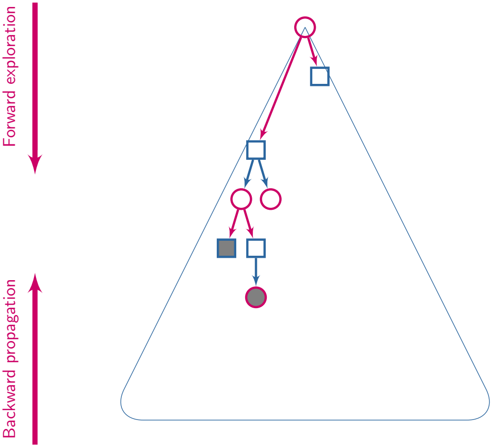

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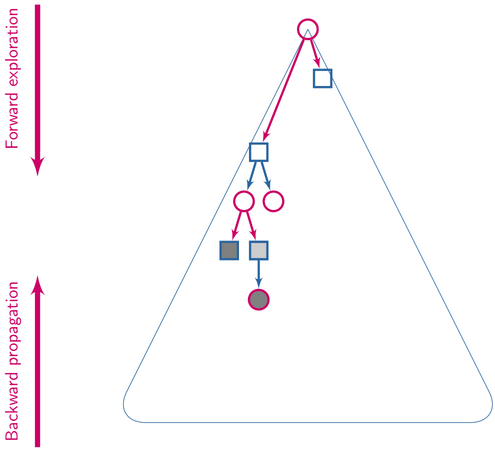

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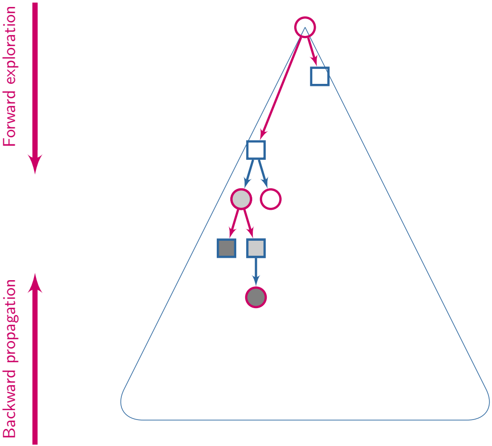

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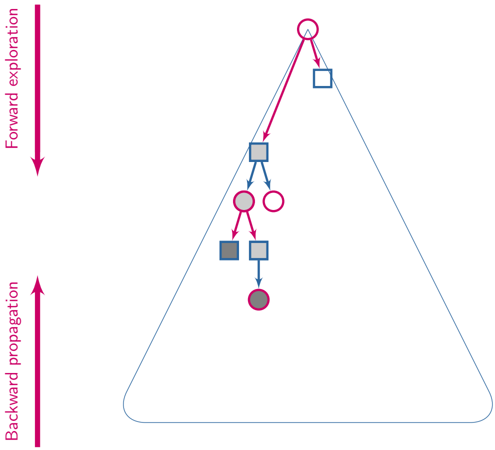

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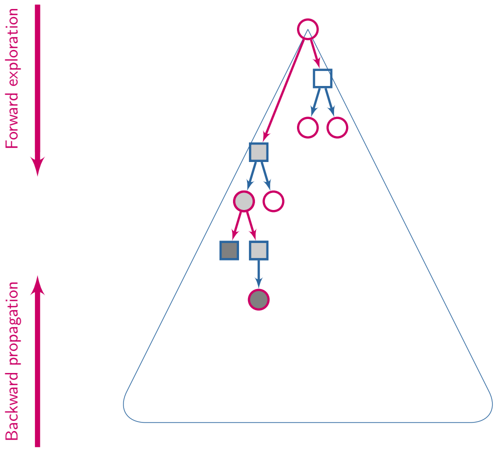

Related work

LTL synthesis [FJR11]: a weaker structure has been identified.

$$\text{simulation relation} + (v \trianglerighteq v' \text{ and } v' \in \mathsf{Lose} \text{ implies } v \in \mathsf{Lose})$$

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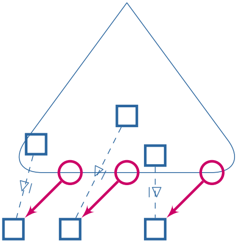
A new optimization

- Optimization 3: partial exploration of winning states

Exploration only
from maximal states



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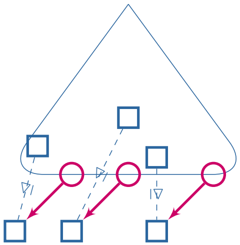

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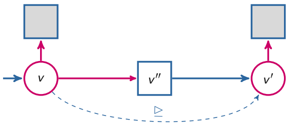

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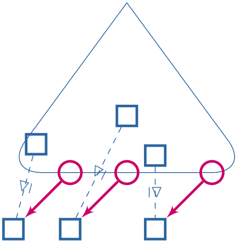

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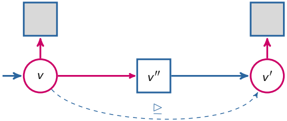
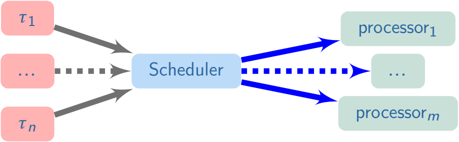
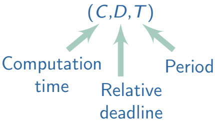


But the relation identified in [FJR11] is an *A*-ready simulation!

Application to real-time scheduling



Sporadic task



[BM10] Feasibility Analysis of Sporadic Real-Time Multiprocessor Task Systems.

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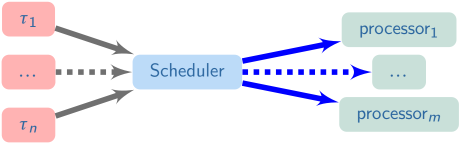

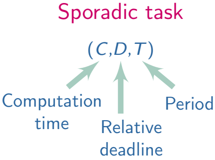

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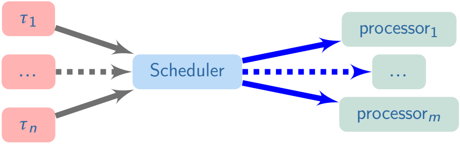

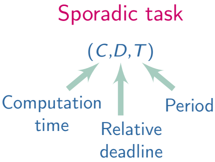

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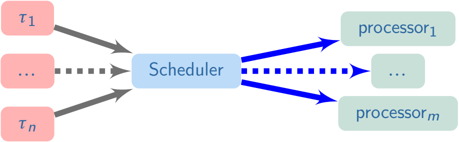

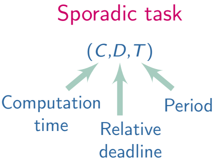

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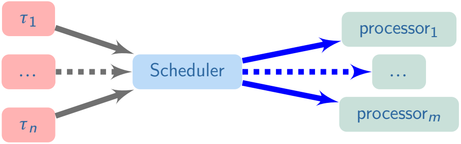

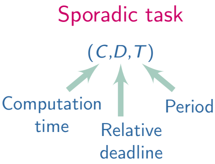

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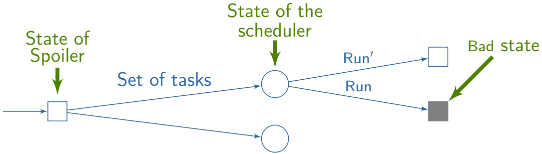

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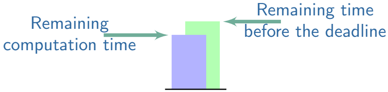
Scheduling game

State of a task:



Scheduling game

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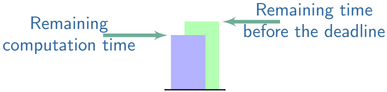

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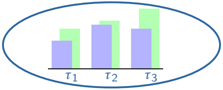

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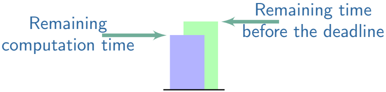

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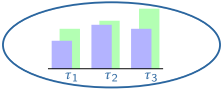

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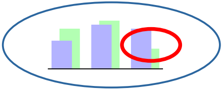

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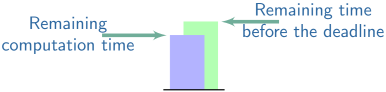

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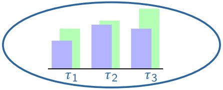

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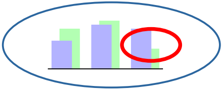
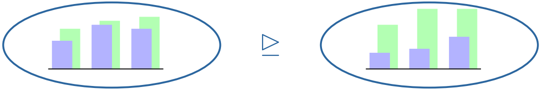


Structure:



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...	...
...	...
v_i	...
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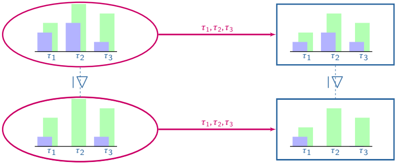
    $\Rightarrow$ apply the same priority order



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  - Other applications
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