Where Ignoring Delete Lists Works, Part II: Causal Graphs

Jörg Hoffmann

INRIA
Nancy, France

June 14, 2011

Outline

- What happened?
- On causal graphs and h^+
- Guaranteed global analysis
- Approximate local analysis
- Diagnosis
- Conclusion

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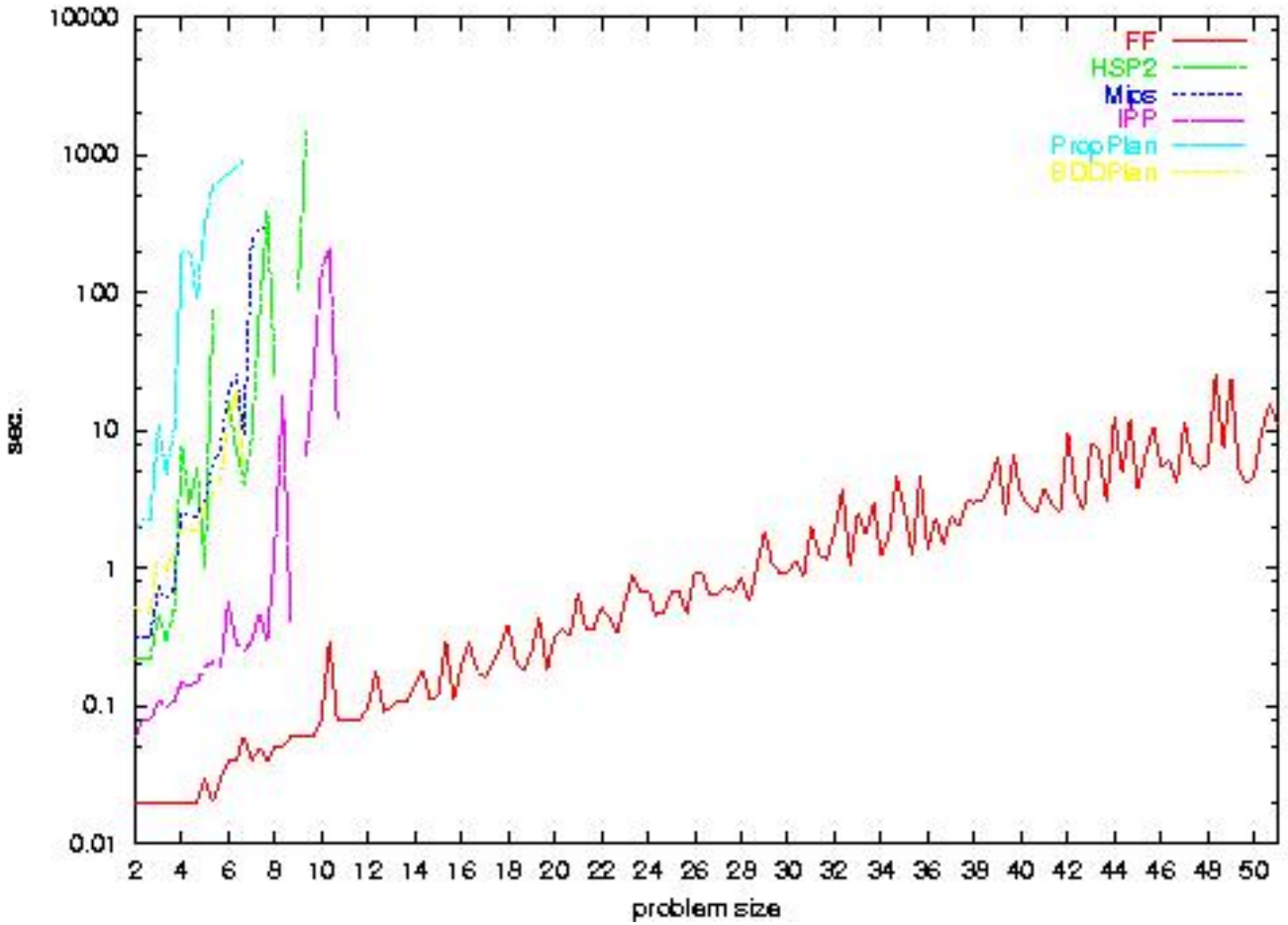
FF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problem size
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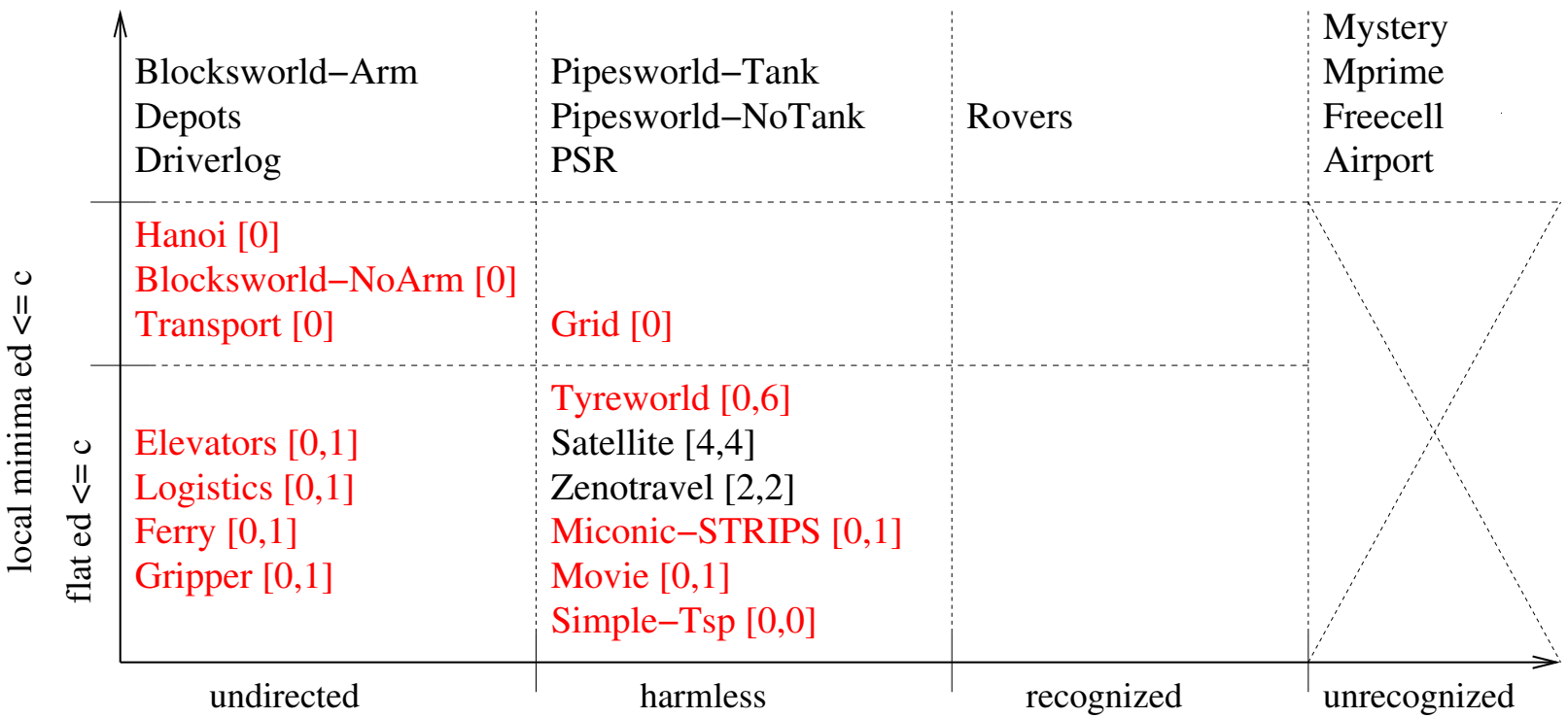
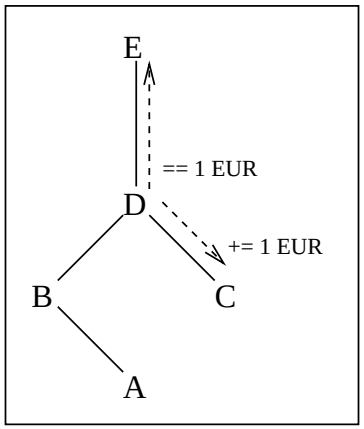
HSP2
Mips
IPP
PropPlan
BDDPlan

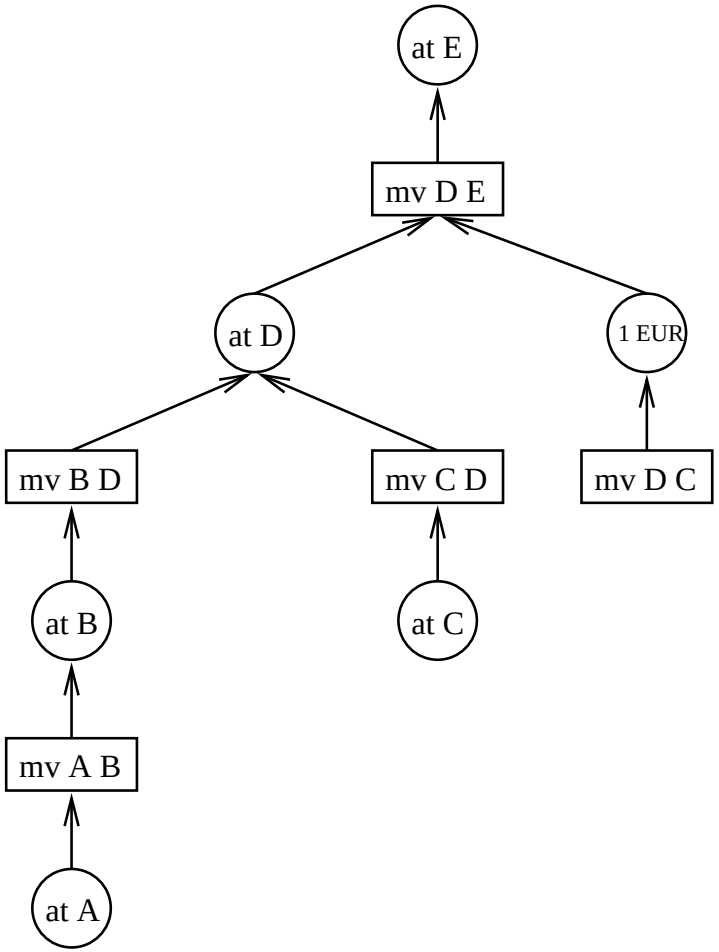
Where Ignoring Delete Lists Works



red: no local minima at all under h^+

Can we recognize this automatically?





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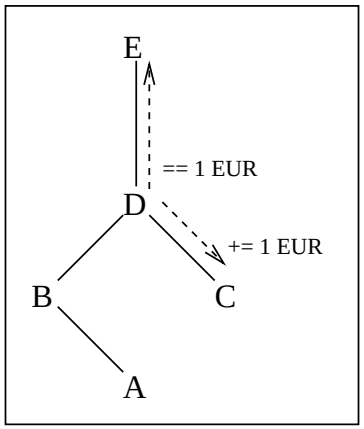

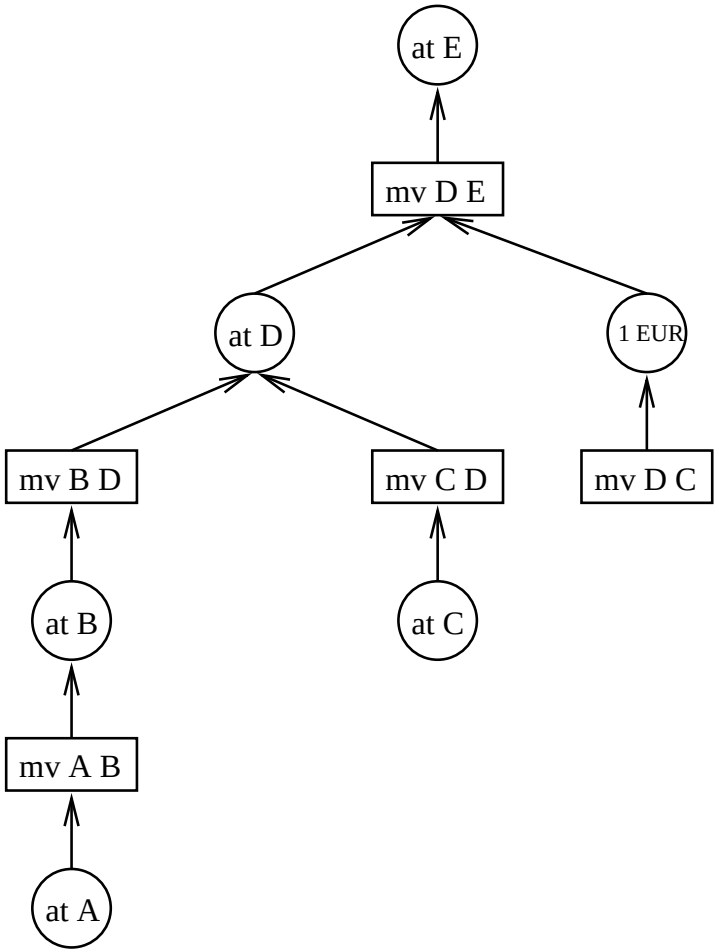

Works *only* in trivialities; explodes quickly

Time passes . . .

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2009

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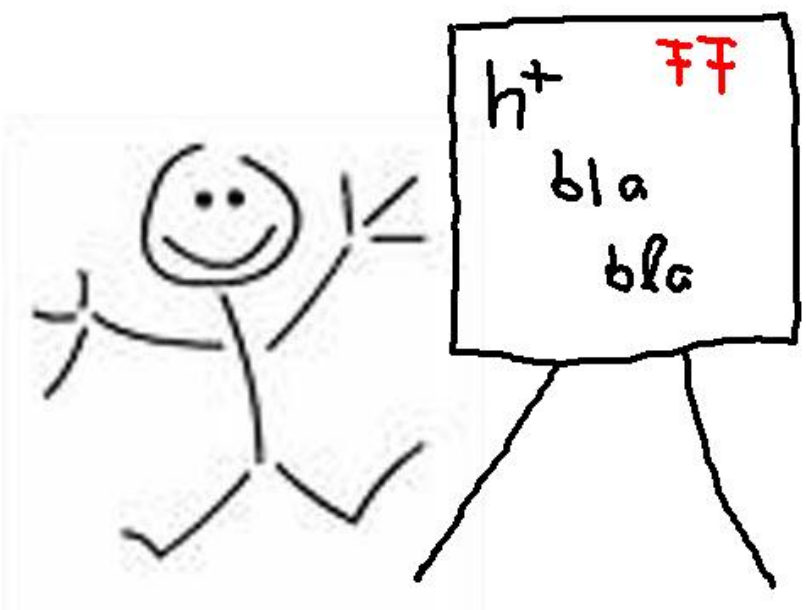

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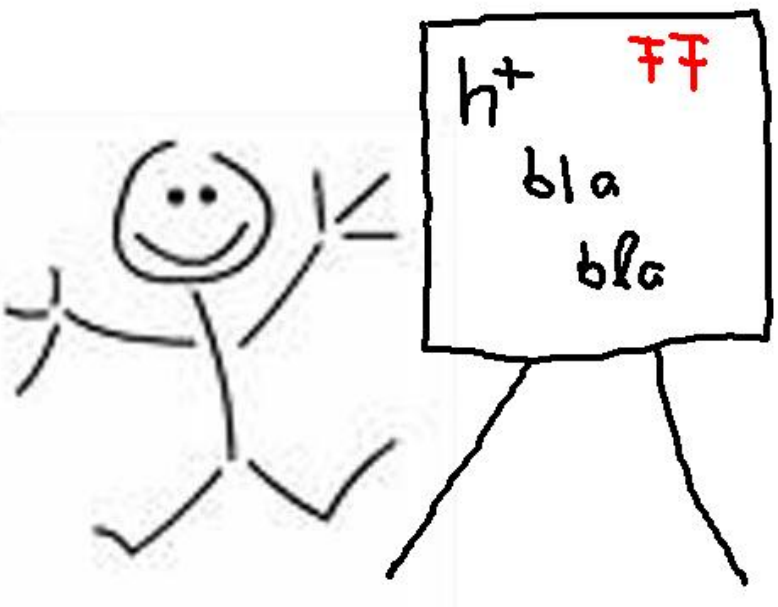

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Luciana Benotti->

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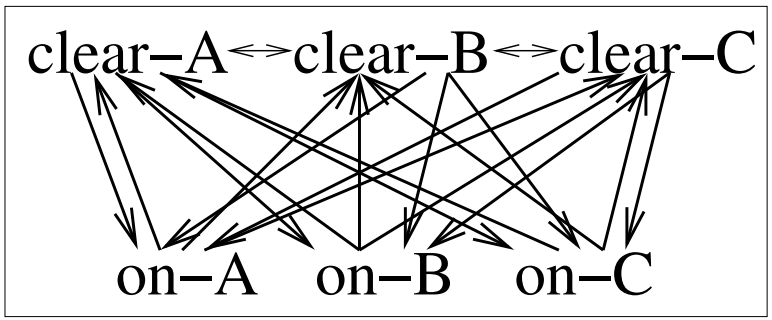
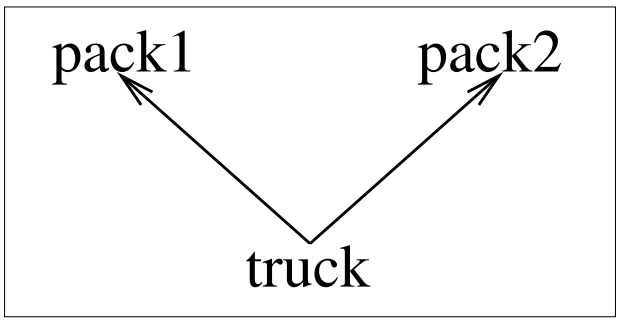
Jörg: **". . .**  **Causal graphs!!!"**

Blocksworld, Logistics, Causal Graphs





The causal graph of Blocksworld contains cycles; h^+ local minima.

That of Logistics doesn't; h^+ no local minima.

Is there a general phenomenon behind this?

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On causal graphs and h^+

Details:

[J. Hoffmann (2011). *Analyzing Search Topology Without Running Any Search: On the Connection Between Causal Graphs and h^+*. Journal of Artificial Intelligence Research, Volume 41: 155-229. **June 2nd** ]

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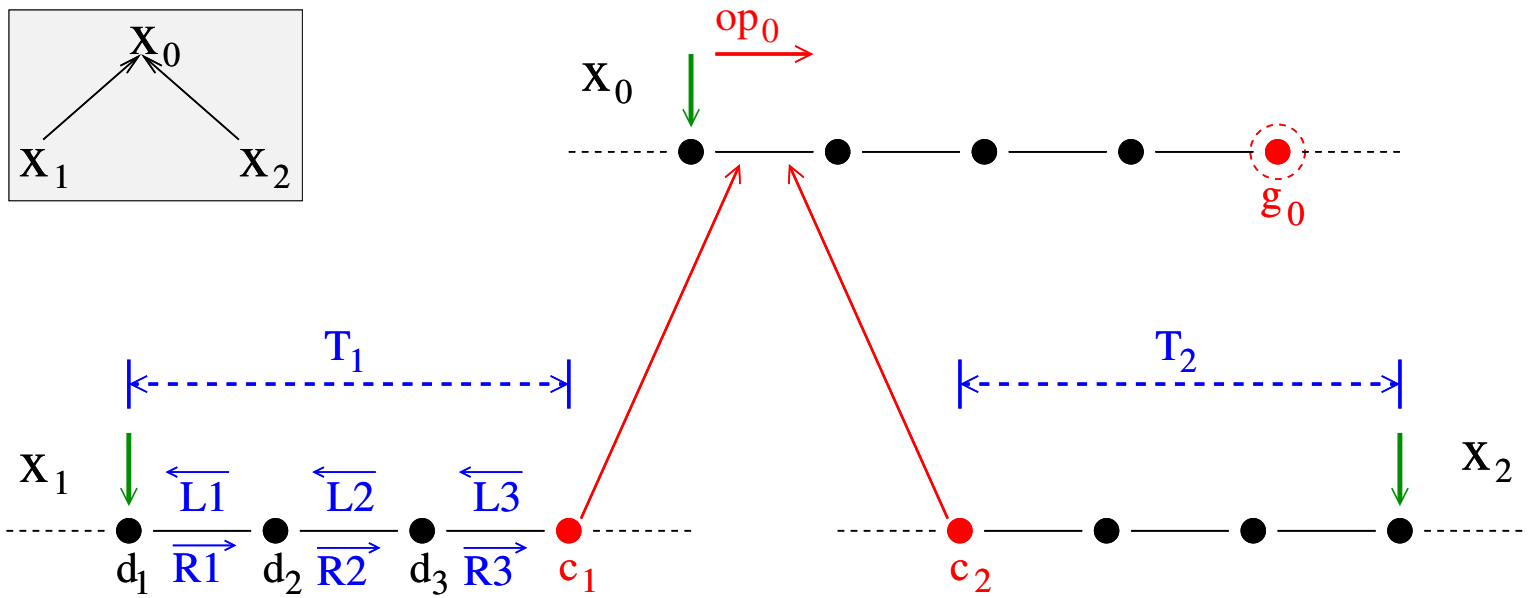

- Finite-domain vars ("SAS$^+$") x_0, x_1, x_2
- Domain transition graphs
- Causal graph: top left
- Transitions invertible + no side effects
- Red: need this; Blue: how to get it; Green: where we are (state s)
- **"Start" state s is not a local minimum!**
- State s_0: $x_1 = c_1$ and $x_2 = c_2$

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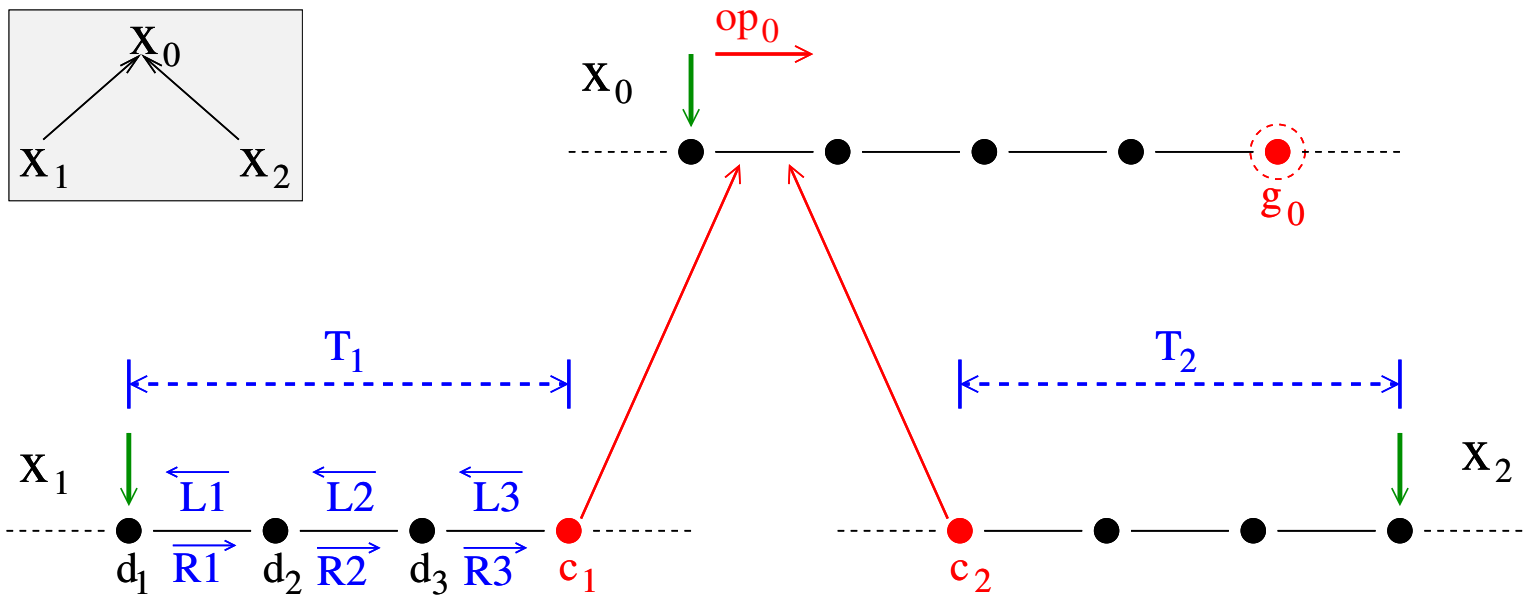

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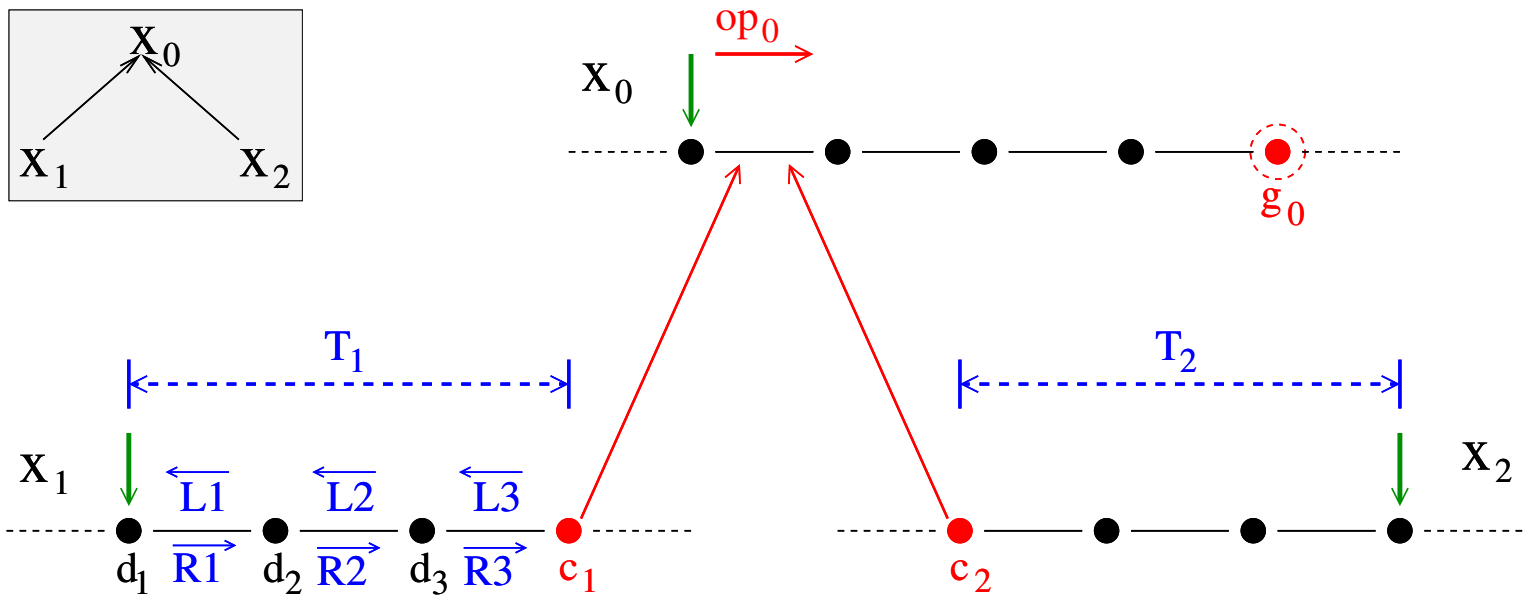

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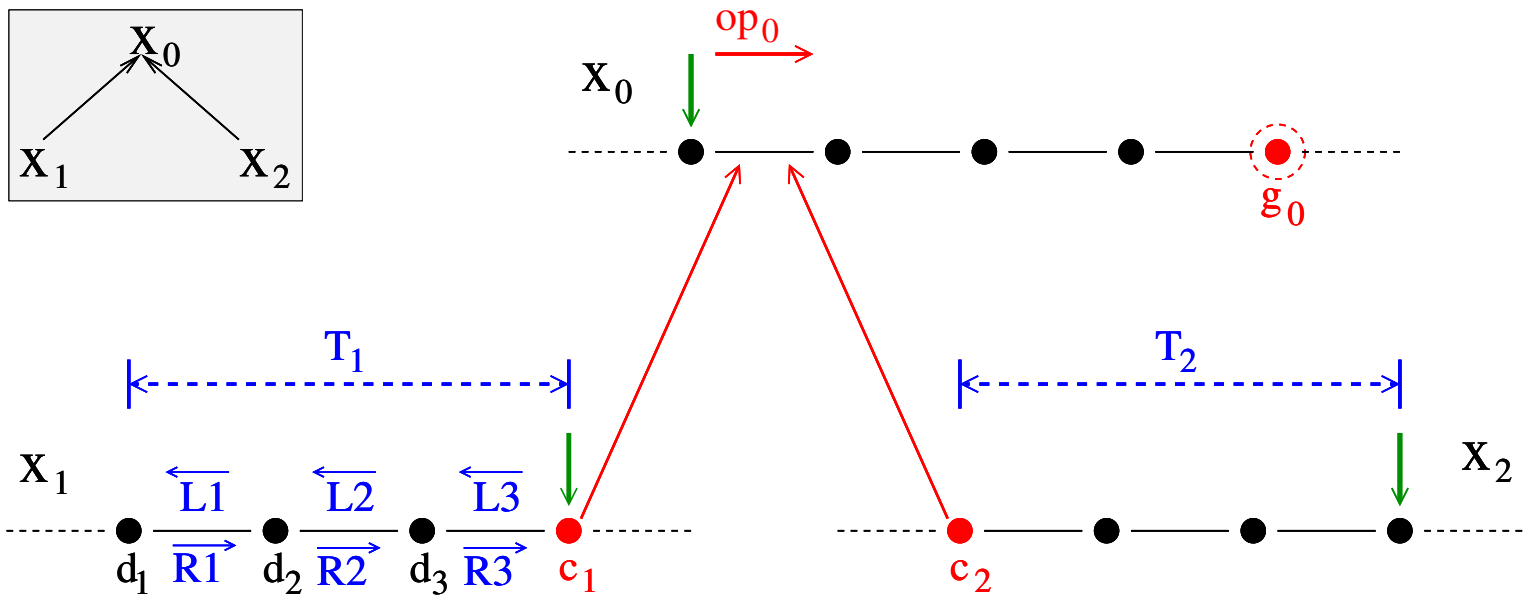

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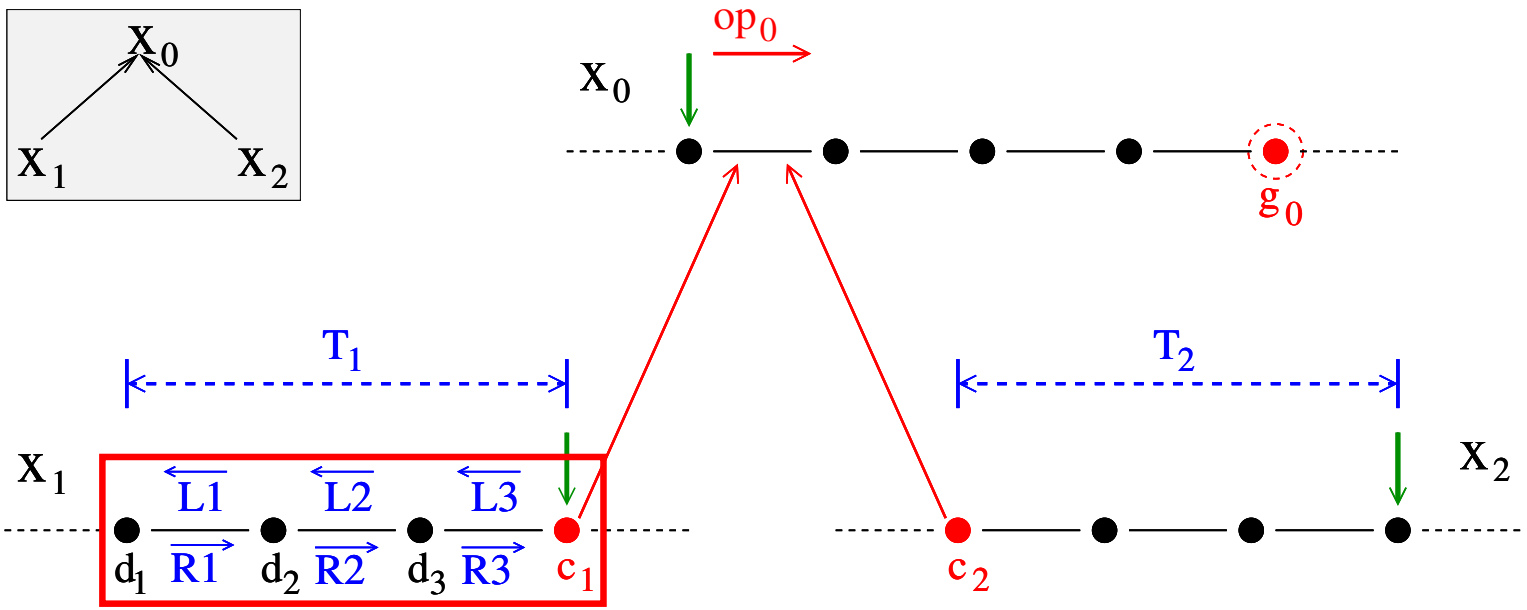

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- $P^+(s') := \langle L3^+, L2^+, L1^+ \rangle \circ P^+$
- $\mathrm{apply}(s, R1^+, R2^+, R3^+)[x_1] = \{d_1, d_2, d_3, c_1\} = \mathrm{apply}(s', L3^+, L2^+, L1^+)[x_1]$

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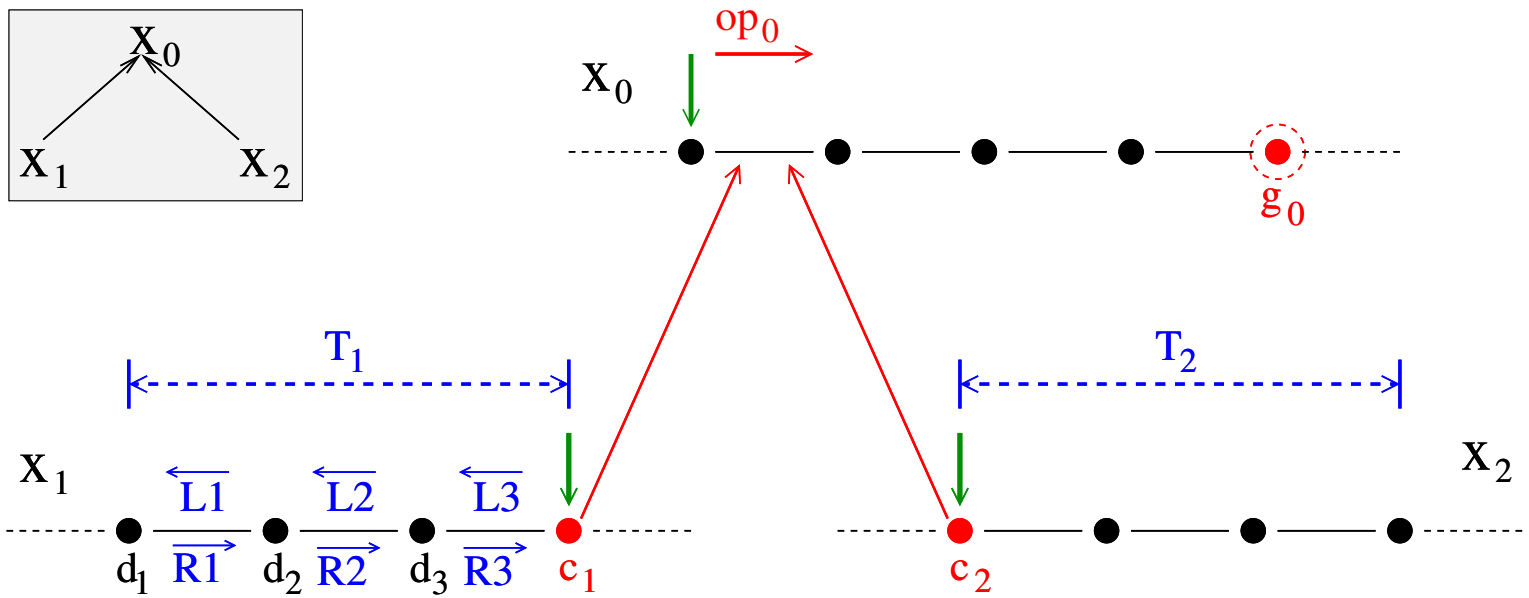

- Say we're in s_0

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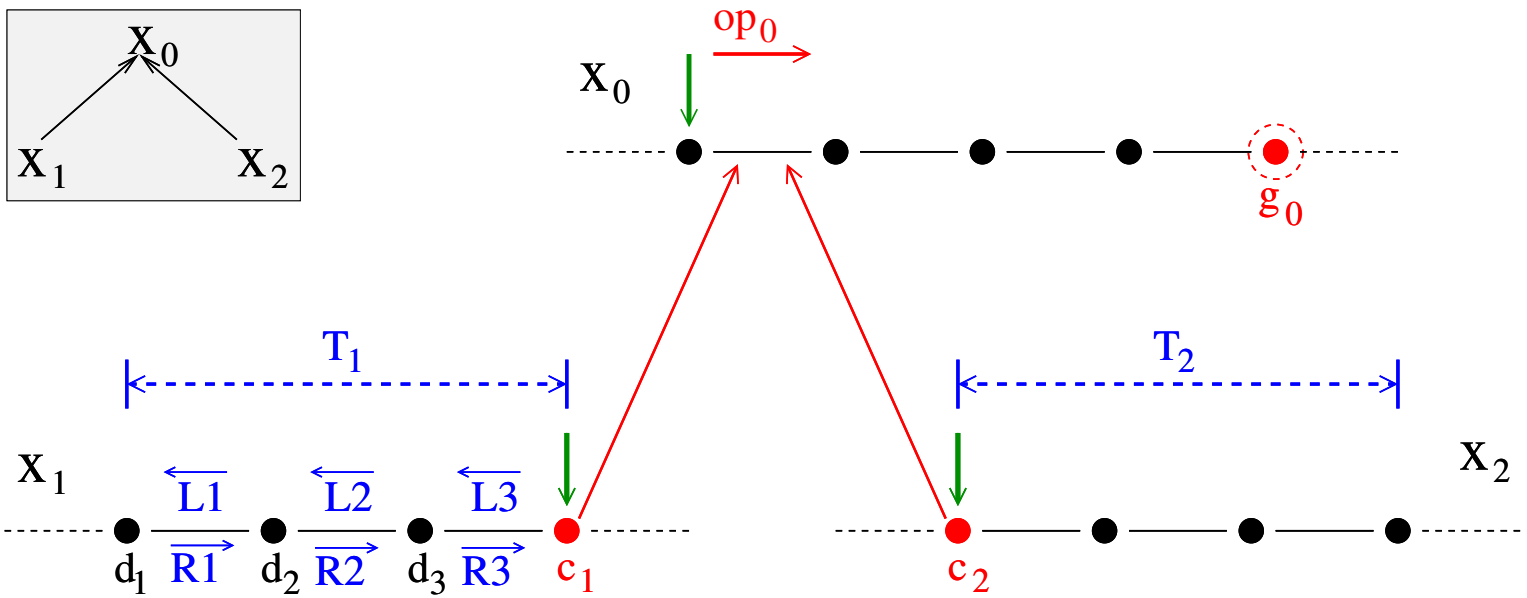

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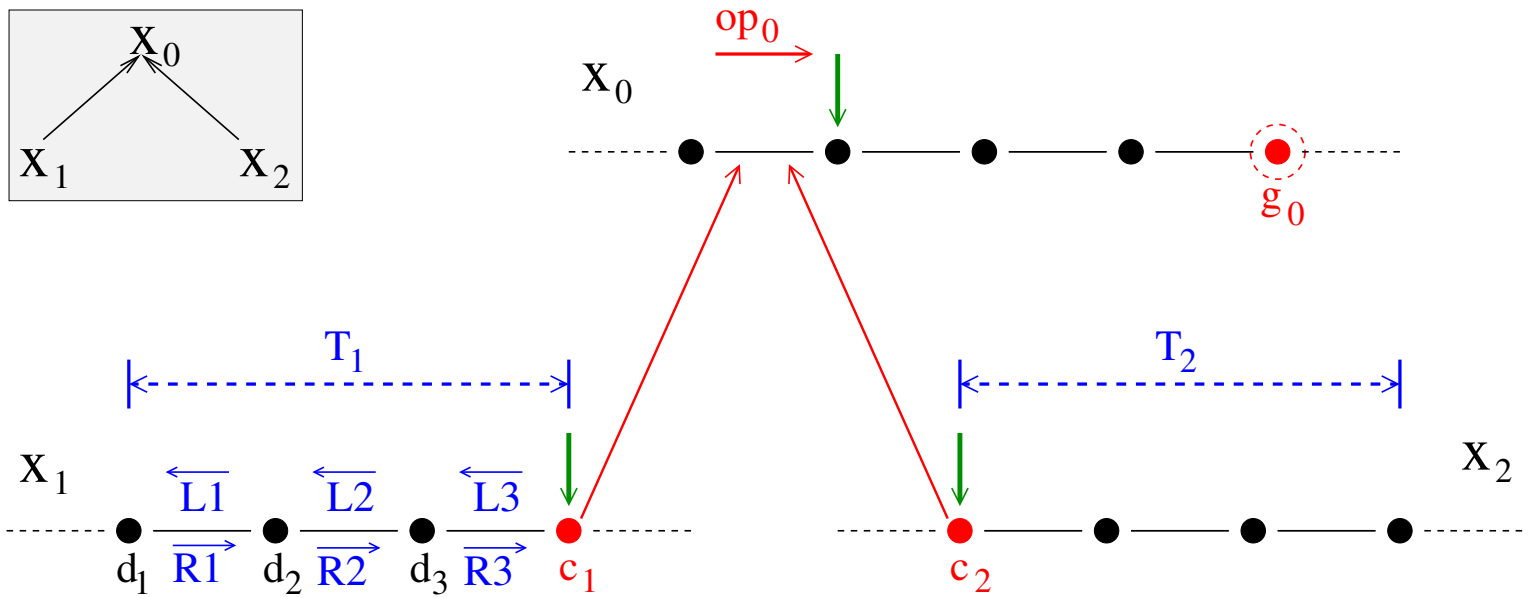

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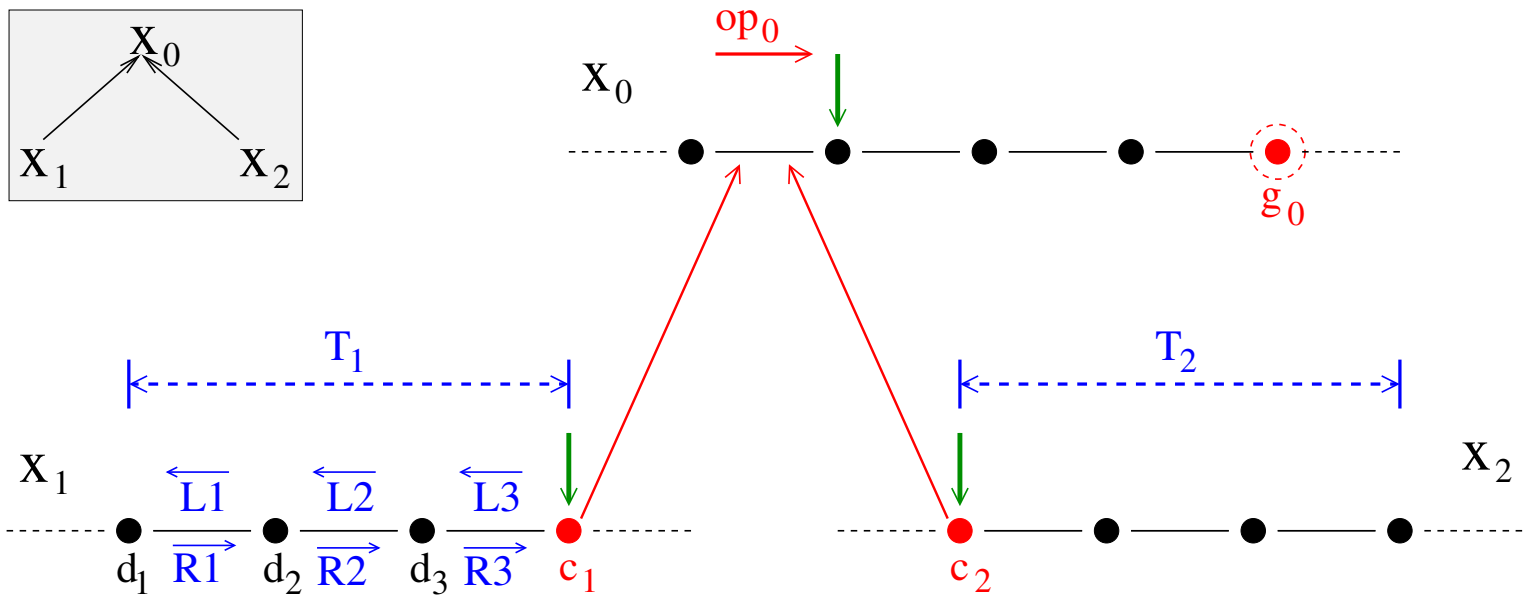

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- $P^+(s_1) := P^+$ (remove op_0 from $P^+(s_0)$); thus $h^+(s_1) < h^+(s)$!!

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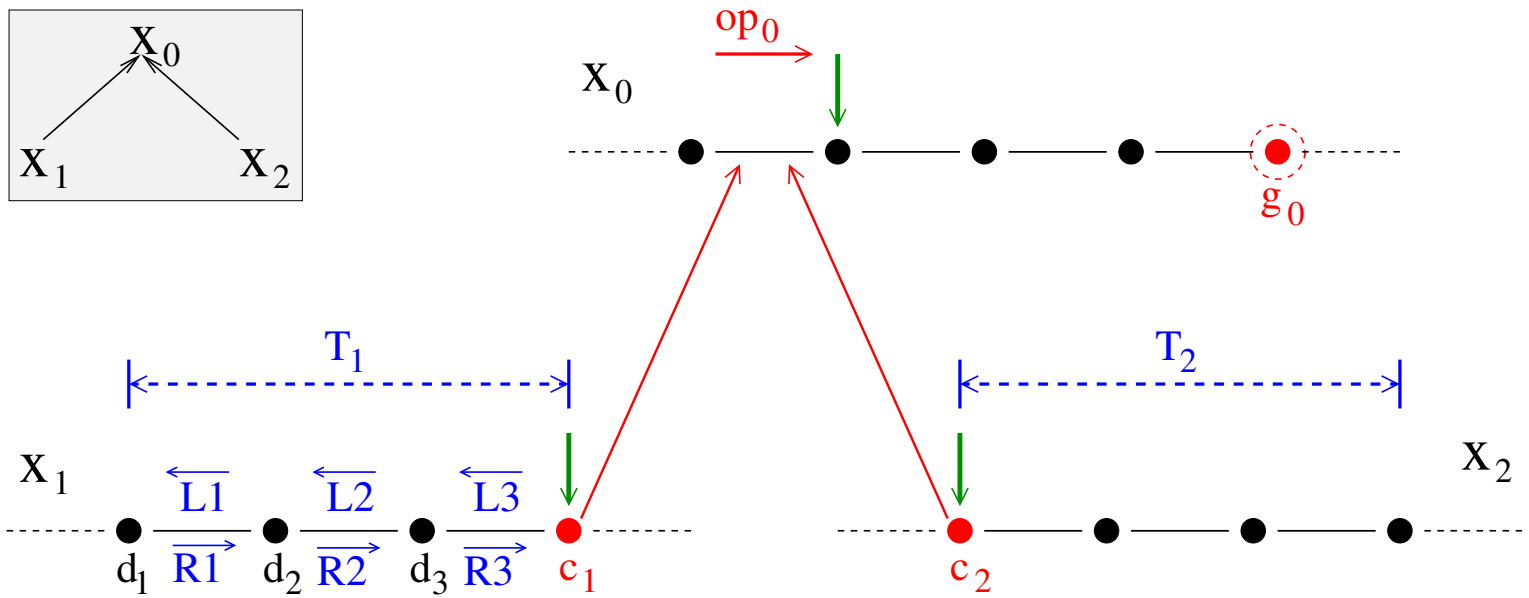

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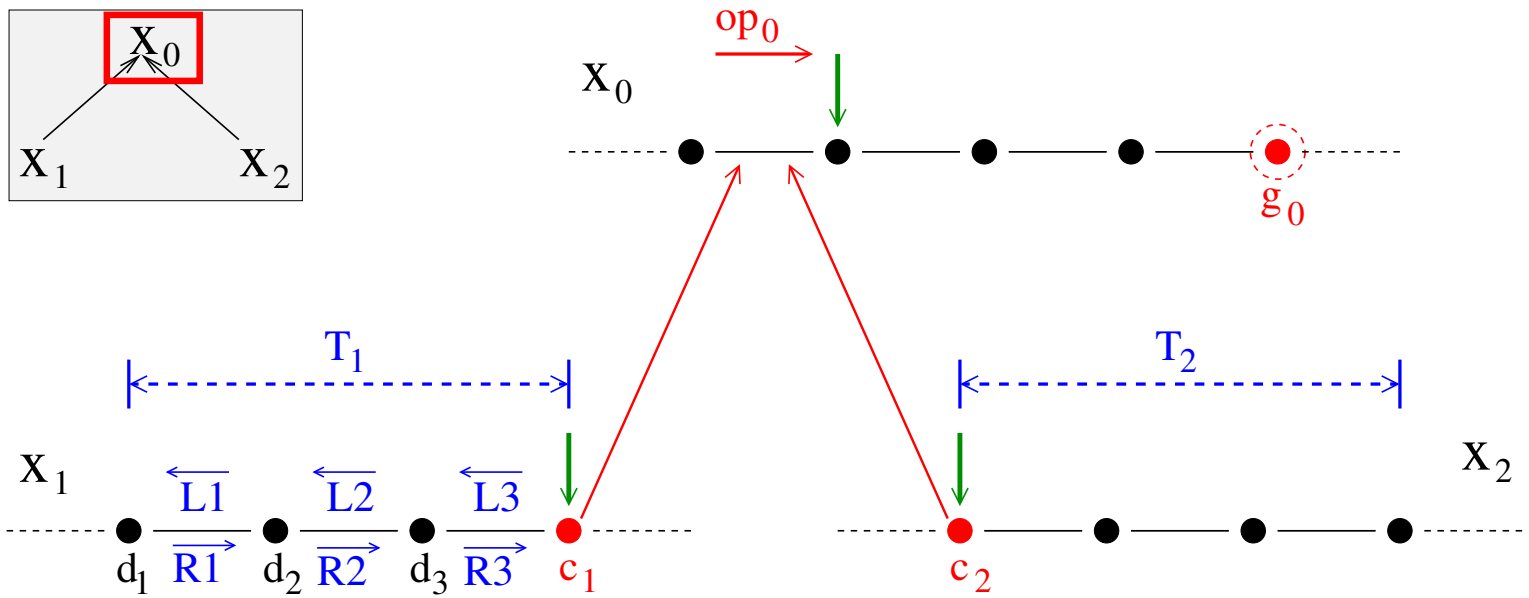

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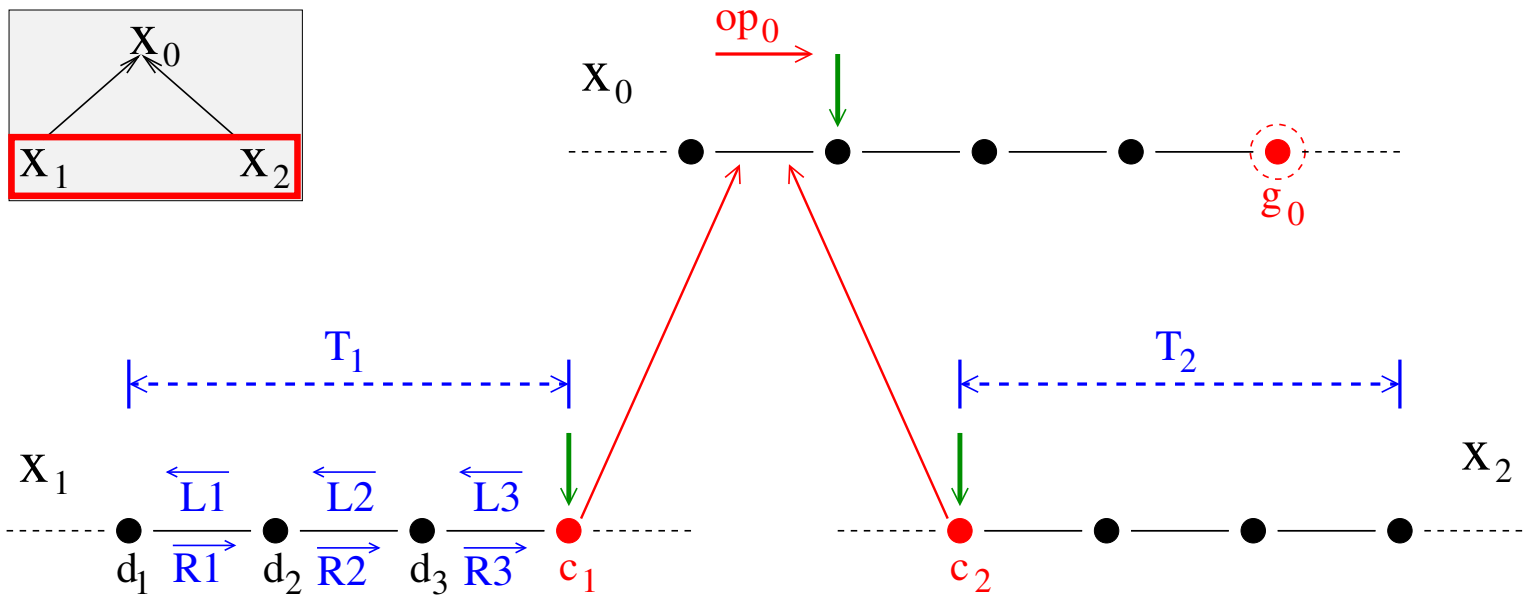

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- x_0 **is CG leaf**
  $\Longrightarrow$ moving x_0 does not affect relaxed plan, thus applying op_0 in s_0 decreases h^+
- Moving x_0 involves **only CG predecessors**; if those have invertible transitions & no cyclic dependencies
  $\Longrightarrow$ can construct path to s_0 with non-increasing h^+

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- **Domain analysis!**

- TorchLight
- Long-term goal: "automatic Hoffmann"

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- Guaranteed global analysis
- Approximate local analysis
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$\Longrightarrow$ TorchLight demo today 17:30 – 20:00

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Guaranteed global analysis

- Prove absence of local minima & global bound on lookahead
- Criterion strictly more general than what we just saw
- Allows e.g. non-unary operators, provided any side-effects are "harmless"

- Recognizes Logistics, Miconic-STRIPS, Movie, SimpleTSP
- Does not recognize anything else just yet . . . [$\frac{4}{12}$ domains]

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Approximate local analysis

- Local: *Is state s not a local minimum?*
- Analyze relaxed plan $P^+(s)$
- Answer "yes" guaranteed correct **if $P^+(s)$ is optimal**
- Theoretically, given optimal $P^+(s)$ as input, recognizes Ferry, Gripper, Elevators, Transport [+ global $= \frac{8}{12}$ domains]
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- Disclaimer:
  - Success rates can also be obtained by trivial search probing
  - Strong theoretical differences; some differences in benchmarks

Hoffmann vs. TorchLight

Zenotravel	Hanoi [0]
Satellite	Airport [0]
Rovers	Blocksworld–Arm [30]
PSR	Mystery [39]
Pipesworld–Tank	Pipesworld–Tank [40]
Pipesworld–NoTank	Mprime [49]
Mystery	PSR [50]
Mprime	Freecell [56]
Freecell	Blocksworld–NoArm [57]
Driverlog	Pipesworld–NoTank [76]
Depots	Grid [80]
Blocksworld–Arm	Depots [81]
Airport	Zenotravel [95]
Tyreworld	Tyreworld [100]
Transport	Transport [100]
Simple–Tsp	Simple–Tsp [100]
Movie	Satellite [100]
Miconic–STRIPS	Rovers [100]
Logistics	Movie [100]
Hanoi	Miconic–STRIPS [100]
Gripper	Logistics [100]
Grid	Gripper [100]
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- Success rate: average per-domain from single sample state per-instance

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- Not all domains are "fully recognized" . . .
- . . . mostly because Hoffmann is too optimistic

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- Success rates are more than a "yes/no" answer!

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- *Which domain aspects cause local minima?*
- *Which unsatisfied conditions caused the analysis to fail?*
- Operator-name/predicate pairs (op, P) where op effect on P prevented use as successful op_0 in approximate local analysis
- Zenotravel: *"fly,fuel-level"*
- Mystery/Mprime: *"feast,locale"*
- Satellite: *"switch-on,calibrated"*
- Rovers: *"take-image,calibrated"*
- This is merely a first-shot technique!

Outline

- What happened?
- On causal graphs and h^+
- Guaranteed global analysis
- Approximate local analysis
- Diagnosis
- **Conclusion**

Conclusion

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Conclusion

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Improving TorchLight:

- Strengthen global anaylsis with complementary techniques
- Derive "good case" characterizations from local analysis?

Using TorchLight:

- Relaxed plan analysis $\Longrightarrow$ macro actions
- Performance prediction (even online during search)
- Abstract by removing (some) harmful effects (diagnosis!)
- Modeling support for planning end-users (diagnosis!)

Last Slide

Thanks. Questions?

p.s. There is an error in these slides. Where?