Implementing a Relevance Tracker Module

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Overview

- Background: SAT(ID)
- Background: Relevance for SAT(ID)
- Implementing Relevance

PC(ID), SAT(ID)

- SAT(ID) = satisfiability check of PC(ID)
- **P**ropositional **C**alculus + **I**nductive **D**efinitions
- PC(ID) encoding $\mathcal{T} = \{p_{\mathcal{T}}, \Delta\}$ (normal form)
- $p_{\mathcal{T}}$ is defined in Δ; must hold for $\mathcal{T}$ to be satisfied.
- Relation with ASP: $p_{\mathcal{T}}$ is a single constraint, all atoms not defined in Δ are *open* (choice rules), Δ contains no recursion over negation (real definition)

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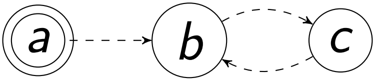
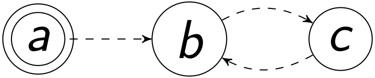
Example

- Choose edges and colors of nodes s.t.
  - node b is reachable from a
  - every node reachable from a is colored green



Example (continued)



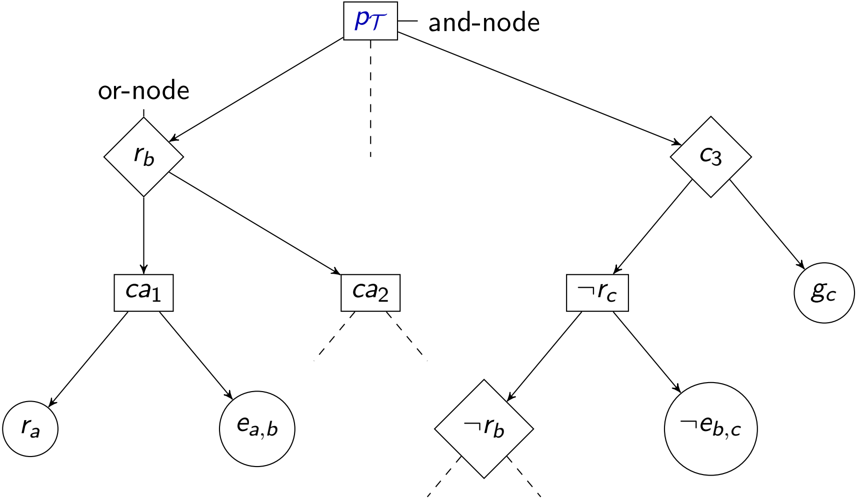
$$\Delta = \left\{ \begin{array}{rcl} {\color{blue} p_{\mathcal{T}}} & \leftarrow & reach_b \ \wedge \ constr_1 \ \wedge \ constr_2 \wedge constr_3. \\ constr_1 & \leftarrow & \neg reach_a \vee green_a. \\ constr_2 & \leftarrow & \neg reach_b \vee green_b. \\ constr_3 & \leftarrow & \neg reach_c \vee green_c. \\ reach_a & . & \\ reach_b & \leftarrow & case_1 \vee case_2. \\ case_1 & \leftarrow & reach_a \wedge edge_{a,b}. \\ case_2 & \leftarrow & reach_c \wedge edge_{c,b}. \\ reach_c & \leftarrow & reach_b \wedge edge_{b,c}. \end{array} \right\}$$

- $reach_x$ = node x is reachable from a
- $constr_x$ = color constraints on node x
- $green_x$ = node x is green
- $edge_{x,y}$ = edge from x to y selected

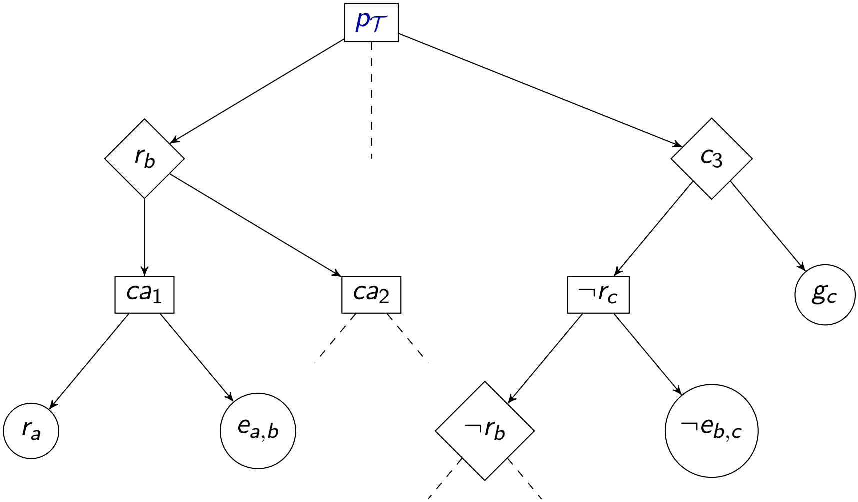
SAT(ID) solver

Typically, a SAT(ID) solver searches for an *assignment (true/false) to all atoms* such that $\mathcal{T}$ is satisfied

Visualising the hierarchy



Visualising the Search process



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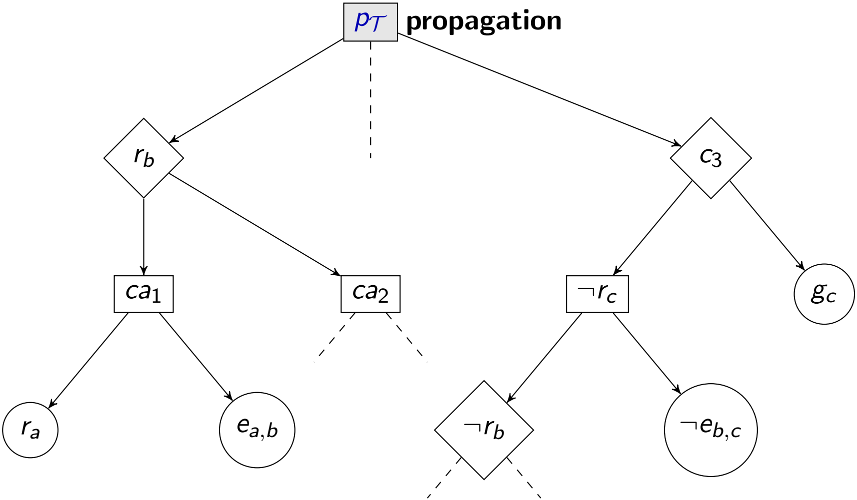

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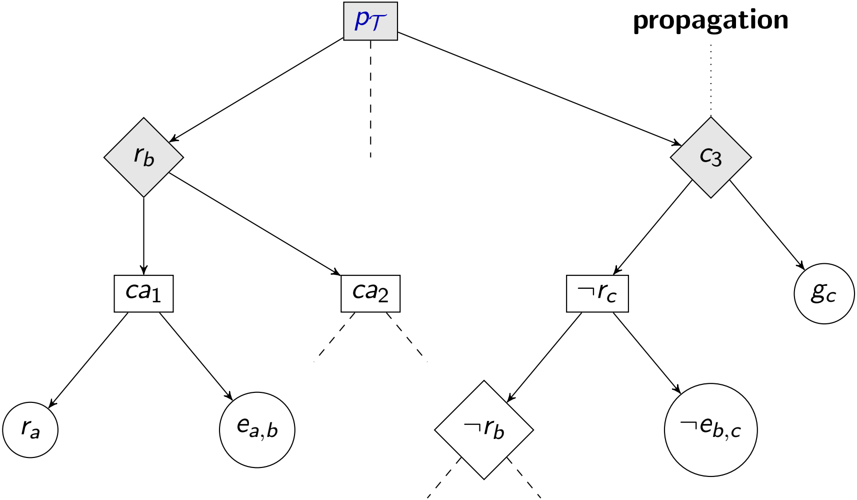
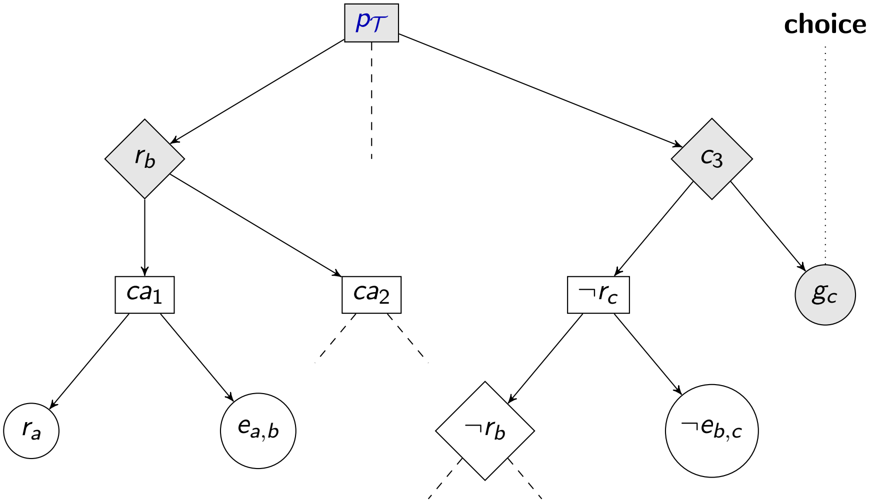


Visualising the Search process



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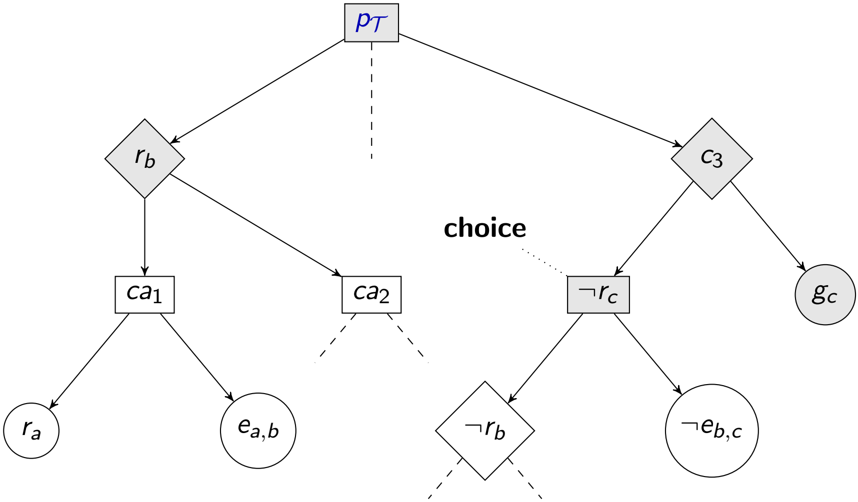

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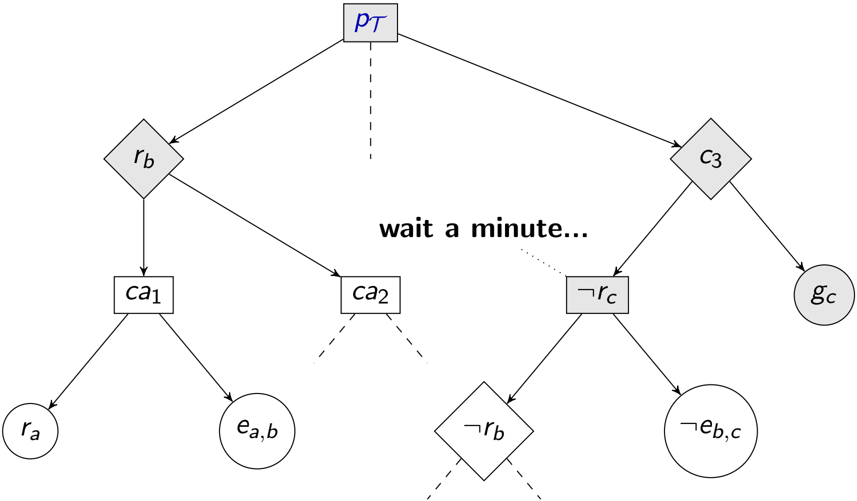
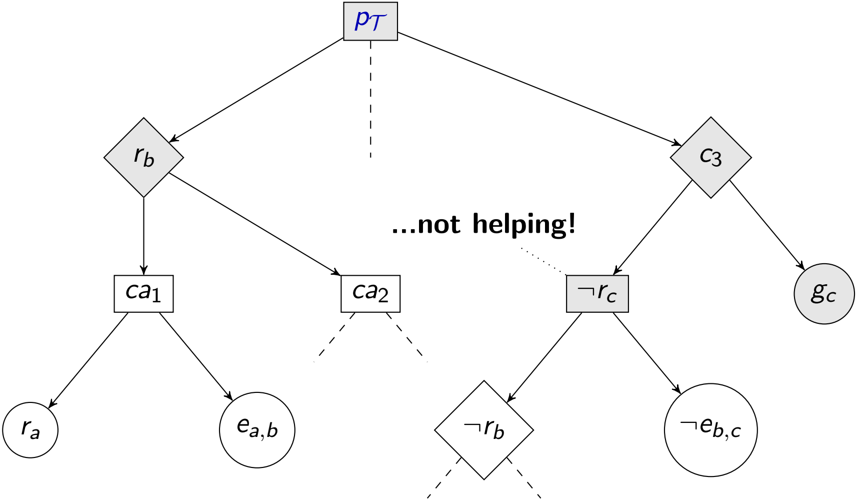


Visualising the Search process



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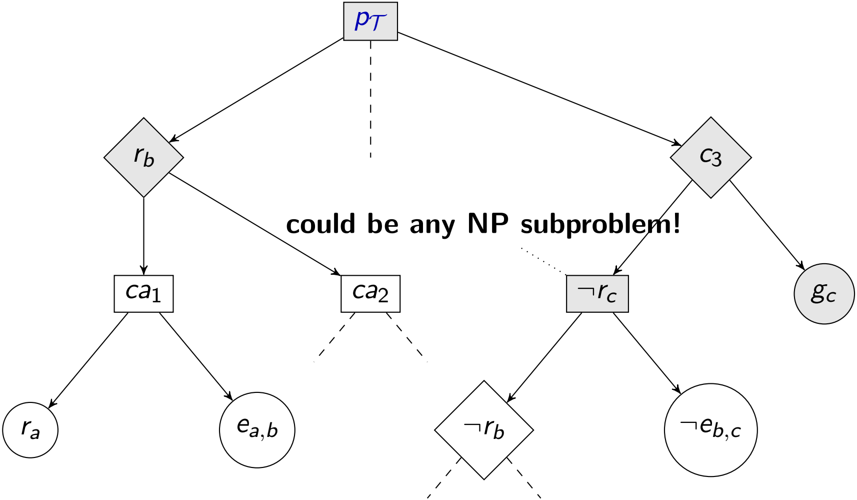

Justifications

- Defined by Denecker and De Schreye (1993) and Denecker, Brewka and Strass (2015)
- Intuitively, a literal is *justified* given a partial assignment if there exists a (recursive) explanation why it must hold in terms of true open literals.

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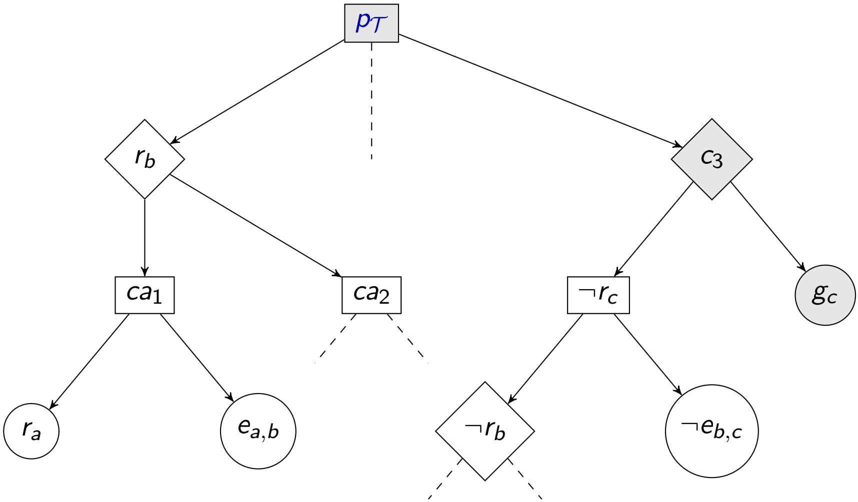
- Intuitively, a literal is *justified* given a partial assignment if there exists a (recursive) explanation why it must hold in terms of true open literals.
- If a literal is justified in a partial assignment, then there exists a model of Δ in which that literal holds.
- Thus... it suffices to prove that $p_{\mathcal{T}}$ is *justified* in some partial interpretation to conclude that $\mathcal{T}$ is satisfiable.

Searching assignment $\rightarrow$ searching $\boxed{\textit{justification}}$



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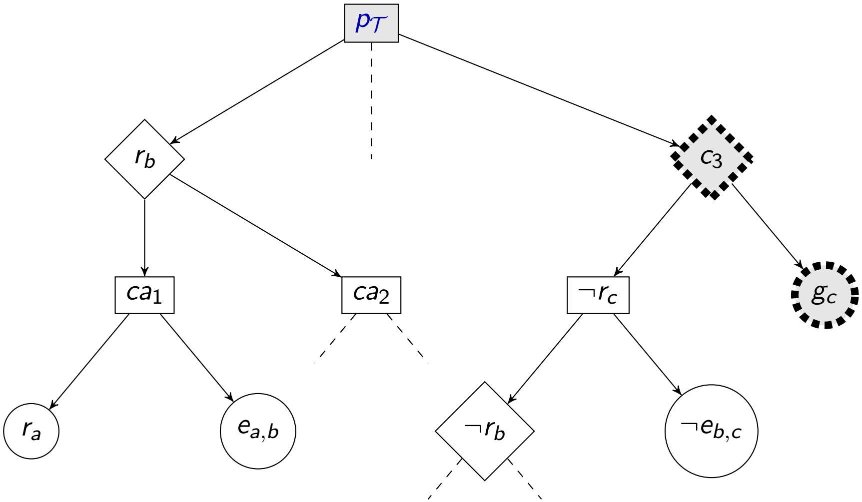
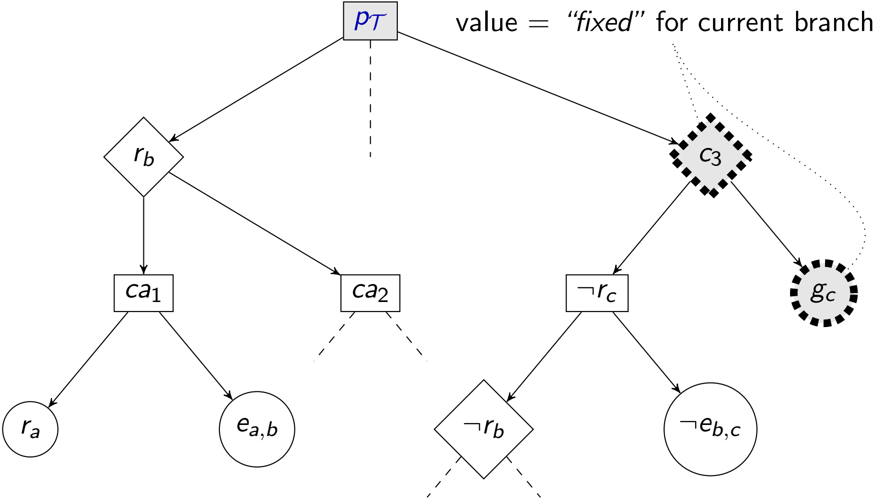


Searching assignment $\rightarrow$ searching *justification*



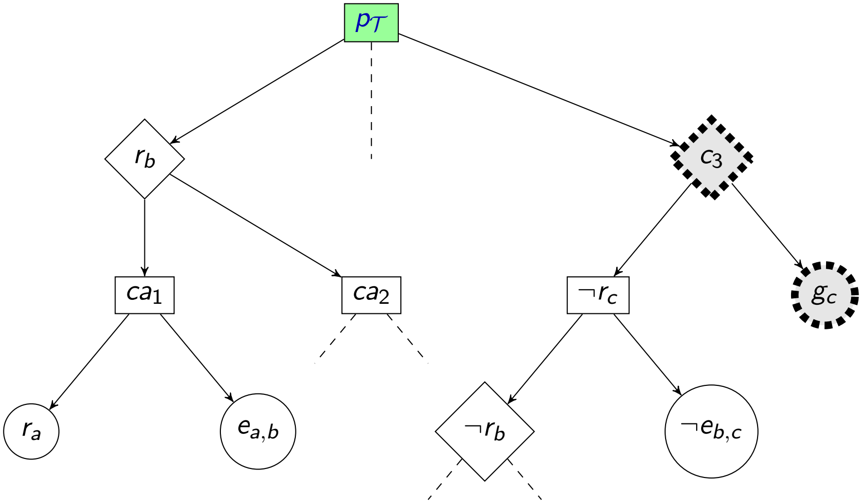
Relevance

Definition

Given a PC(ID) theory $\mathcal{T} = \{p_{\mathcal{T}}, \Delta\}$ and a partial interpretation $\mathcal{I}$, we inductively define the set of relevant literals, denoted $\mathcal{R}_{\mathcal{T},\mathcal{I}}$, as follows

- $p_{\mathcal{T}}$ is relevant if $p_{\mathcal{T}}$ is not justified,
- l is relevant if l is not justified and there exists some l' such that $(l', l) \in dd_{\Delta}$ and l' is relevant.

Relevant $\approx$ can help justify $p_{\mathcal{T}}$



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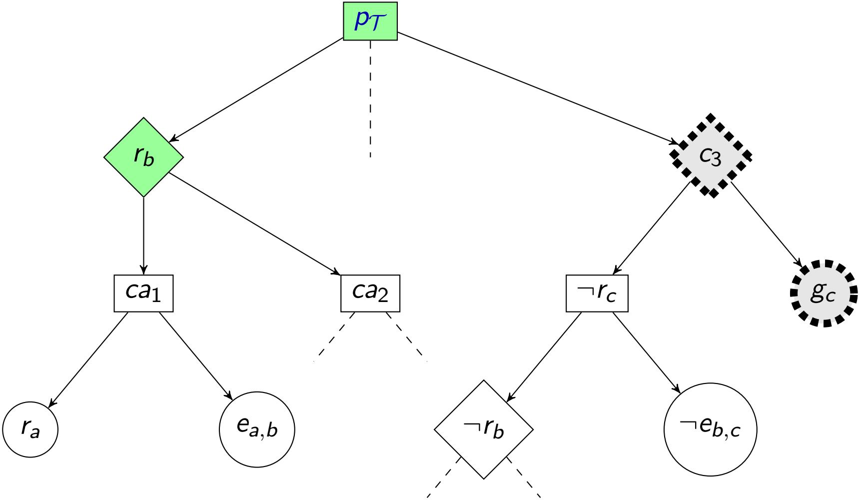

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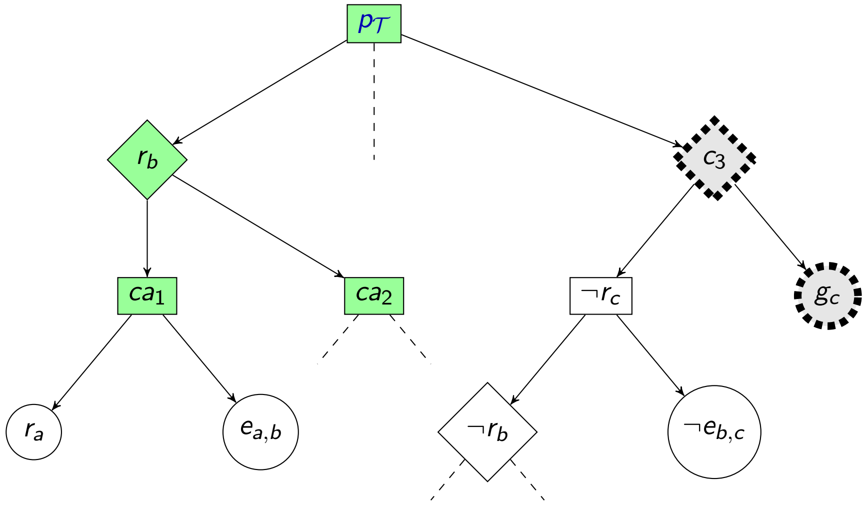

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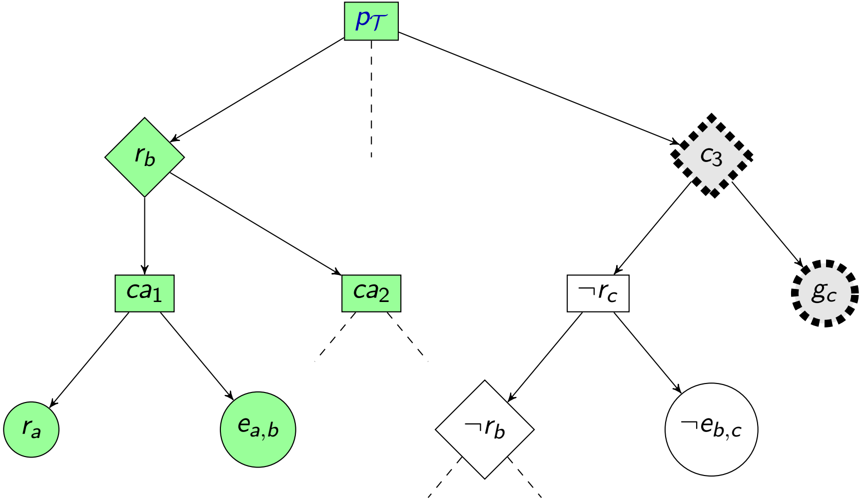

Adjusting the Solver

- Decide only on $\boxed{\textit{Relevant}}$ literals.
- Stop search when $p_{\mathcal{T}}$ is *justified*
  - Guarantee that a two-valued solution can be generated efficiently
  - More tolerant to faulty choices of the solver
  - Expectation: less choices made by solver

Implementation

- How to keep track of justified literals?
- How to keep track of relevant literals?

Keeping track of justified literals

- For each defined atom p, introduce a new atom j_p.
- Intended interpretation: j_p is true (in a partial interpretation) iff p is justified; j_p is false iff $\neg p$ is justified; j_p is unknown otherwise.
- Duplicate definition Δ to a new definition Δ', obtained by a replacing each defined atom p by j_p (note: open literals remain).
- Modify solver: forbidden to make choices on j_p.
- **Claim**: after the standard propagation is executed, j_p satisfies the "intended interpretation" above.

Keeping track of justified literals

Theorem

Let Δ be a (total) definition and $\mathcal{I}$ a partial interpretation in which all defined symbols of Δ are interpreted as $\mathbf{u}$. Let l be a defined literal in Δ. In this case l is justified in $\mathcal{I}$ if and only if l is derivable by unit propagation on the completion of Δ and unfounded set propagations.

Keeping track of justified literals

- Without major modifications to the solver, we obtain a method to keep track of justified literals.
- Only modification: do not make choices on certain atoms.

Keeping track of relevant literals

Recall:

Definition

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- $p_{\mathcal{T}}$ is relevant if $p_{\mathcal{T}}$ is not justified,
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Keeping track of relevant literals

- For each relevant literal (except $p_{\mathcal{T}}$), we maintain one *relevant parent in* dd_Δ: the *reason* why this literal is relevant.
- Thus, we maintain a subgraph of dd_Δ.
- We incrementally update this subgraph (as the justification status of certain literals changes)
- Biggest challenge: keeping this graph acyclic. (how to choose the "right" parent)

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- Thus, we maintain a subgraph of dd_{Δ}.
- We incrementally update this subgraph (as the justification status of certain literals changes)
- Biggest challenge: keeping this graph acyclic. (how to choose the “right” parent)
- Turns out... this cycle detection is the same problem as tackled in unfounded set propagators.
- Only difference: works on a (slightly) different graph.

Keeping track of relevant literals

- In the paper, we also detail the used data structures and an event-driven implementation

Experiment Setup (1)

- Problems from previous ASP competitions
- Solver = Minisatid, Heuristic = VSIDS

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- Measuring
  - Ratio of irrelevant decisions (**%**)
  - Ratio of conflicts originating from irrelevant decisions (**%**)

Experimental Results (1)

Problem	% Irr. **Decisions**	% Irr. **Conflicts**
HP	27.37%	36.99%
NQueens	22.55%	0.43%
PPM	22.93%	4.98%
Sokoban	48.20%	0.96%
Solitaire	13.32%	3.95%
SM	96.40%	0.01%
Visit All	15.02%	16.45%

Experiment Setup (2)

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  - Number of decisions (#)
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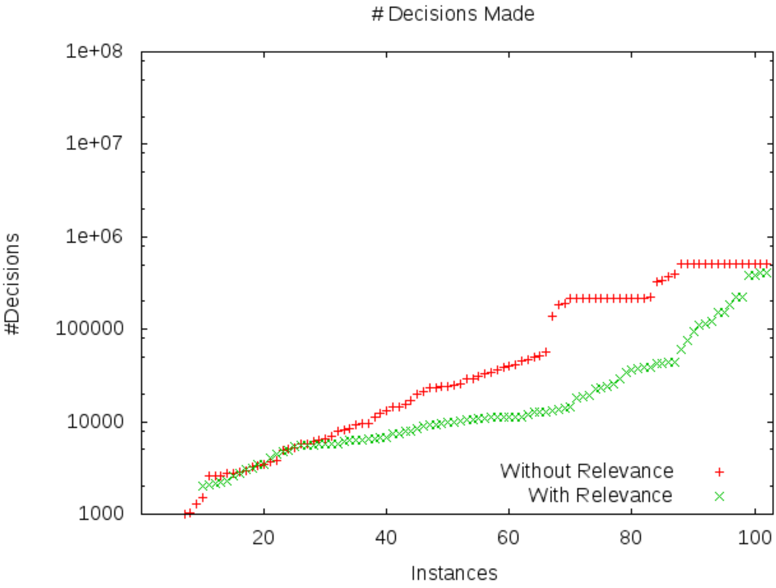

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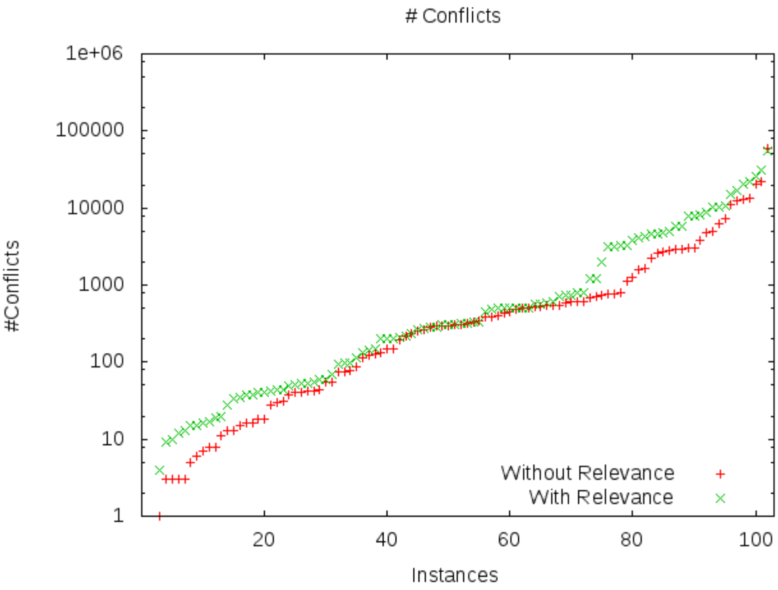

Take-away messages

- Exploit problem hierarchy using $\boxed{\textit{Relevance}}$

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- Exploit problem hierarchy using $\boxed{\textit{Relevance}}$
- Preliminary promising results: fewer *decisions*
- A relevance tracker can be *implemented* reusing existing methods:
  - Justification status: unit propagation and unfounded set propagation
  - Relevance status: unfounded set algorithms

Questions?