

Implementing a Relevance Tracker Module

Joachim Jansen¹, Bart Bogaerts^{2,1}, Jo Devriendt¹
Gerda Janssens¹, Marc Denecker¹

1 KU Leuven, Belgium, firstname.lastname@kuleuven.be

2 Aalto University, Finland, bart.bogaerts@aalto.fi

October 16th, 2016

The logo for KU Leuven, featuring the text "KU LEUVEN" in white, bold, uppercase letters on a dark blue rectangular background with a light blue border.

KU LEUVEN

The logo for Aalto University School of Science, featuring a large black letter "A" with a red exclamation mark to its right, and the text "Aalto University School of Science" below it.

A!
Aalto University
School of Science

Overview

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

PC(ID), SAT(ID)

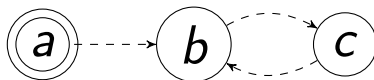
- ▶ SAT(ID) = satisfiability check of PC(ID)
- ▶ **P**ropositional **C**alculus + **I**nductive **D**efinitions
- ▶ PC(ID) encoding $\mathcal{T} = \{p_{\mathcal{T}}, \Delta\}$ (normal form)
- ▶ $p_{\mathcal{T}}$ is defined in Δ ; must hold for \mathcal{T} to be satisfied.
- ▶ Relation with ASP: $p_{\mathcal{T}}$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

PC(ID), SAT(ID)

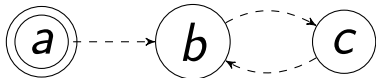
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Example

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



Example (continued)



$$\Delta = \left\{ \begin{array}{l} p_T \leftarrow reach_b \wedge constr_1 \wedge constr_2 \wedge constr_3. \\ constr_1 \leftarrow \neg reach_a \vee green_a. \\ constr_2 \leftarrow \neg reach_b \vee green_b. \\ constr_3 \leftarrow \neg reach_c \vee green_c. \\ reach_a \quad . \\ reach_b \leftarrow case_1 \vee case_2. \\ case_1 \leftarrow reach_a \wedge edge_{a,b}. \\ case_2 \leftarrow reach_c \wedge edge_{c,b}. \\ reach_c \leftarrow reach_b \wedge edge_{b,c}. \end{array} \right.$$

► $reach_x$ = node x is reachable from a

► $constr_x$ = color constraints on node x

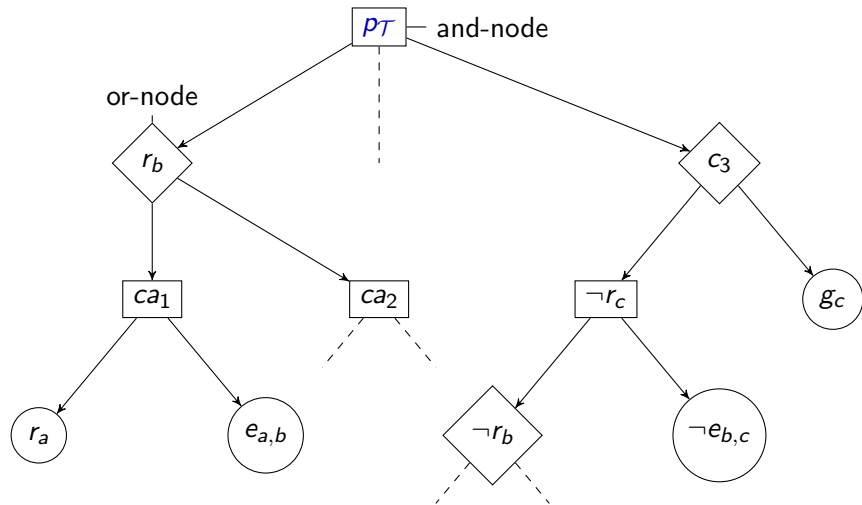
► $green_x$ = node x is green

► $edge_{x,y}$ = edge from x to y selected

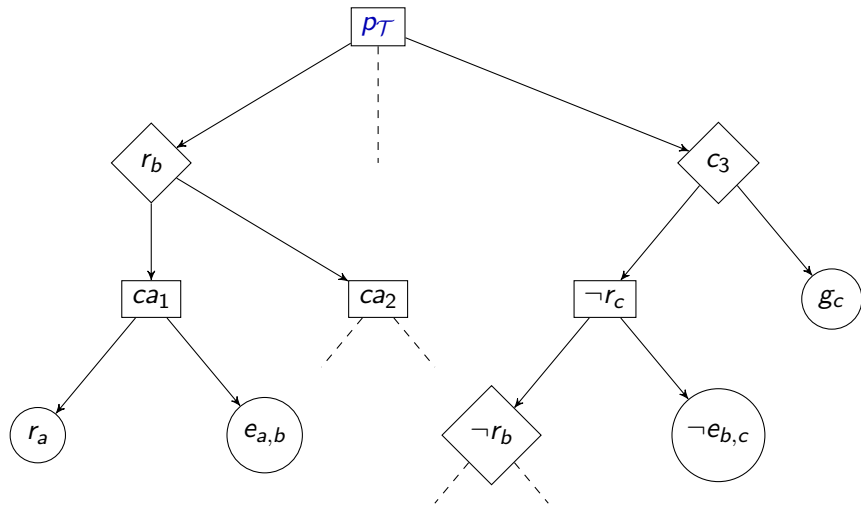
SAT(ID) solver

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

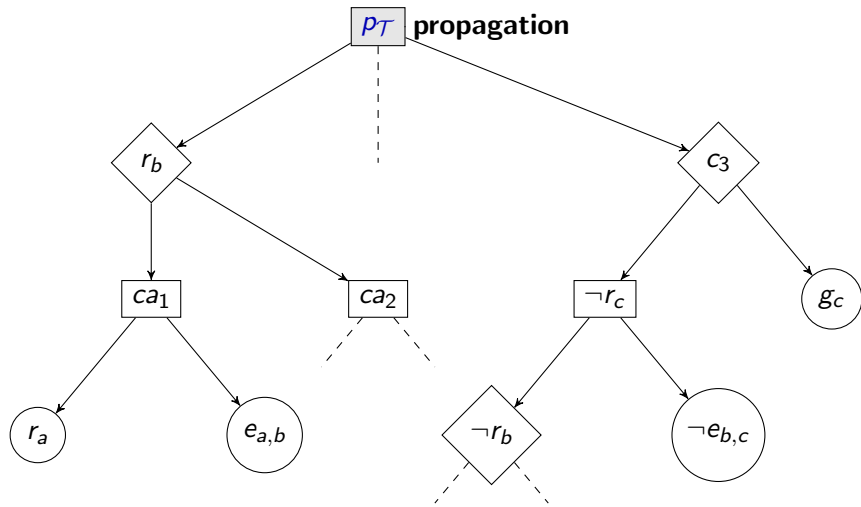
Visualising the hierarchy



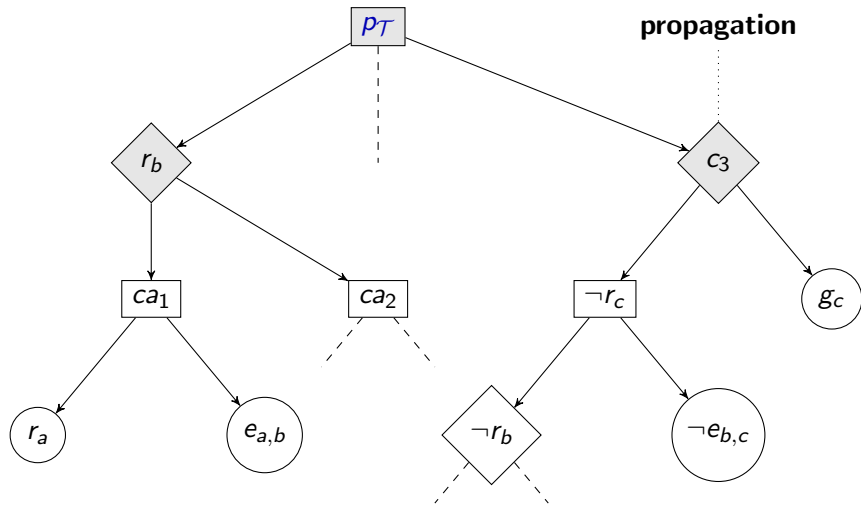
Visualising the Search process



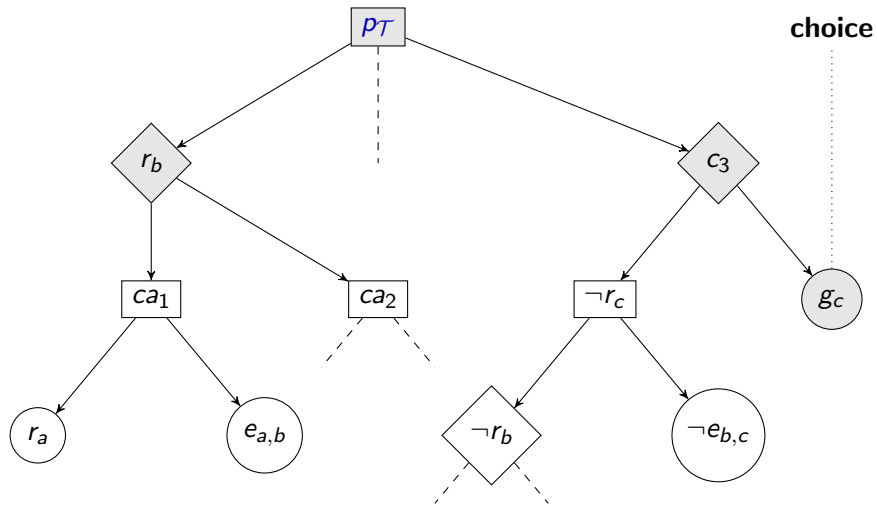
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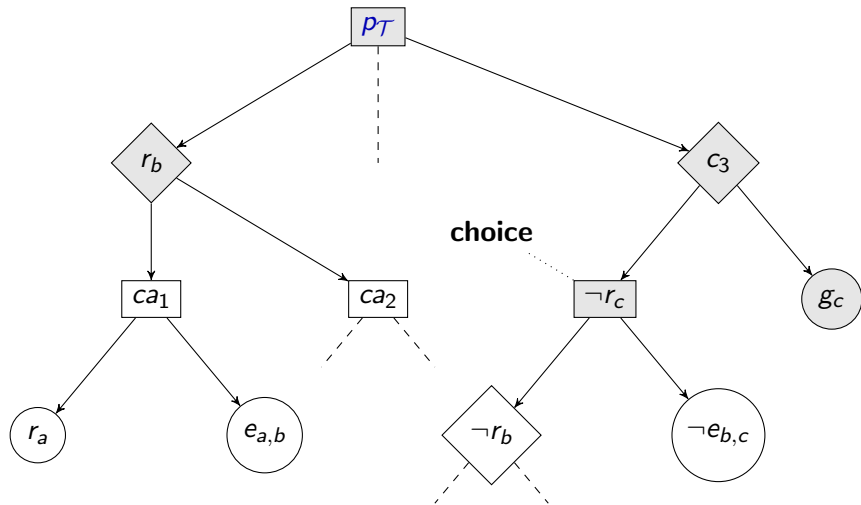
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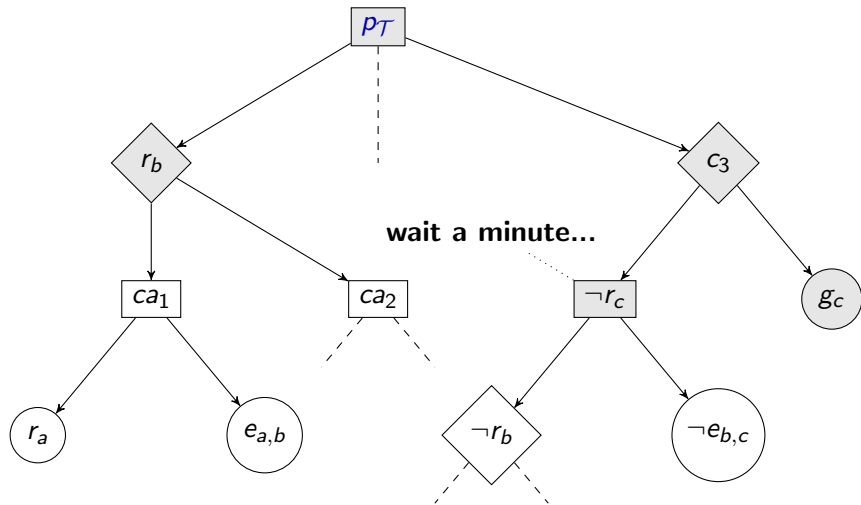
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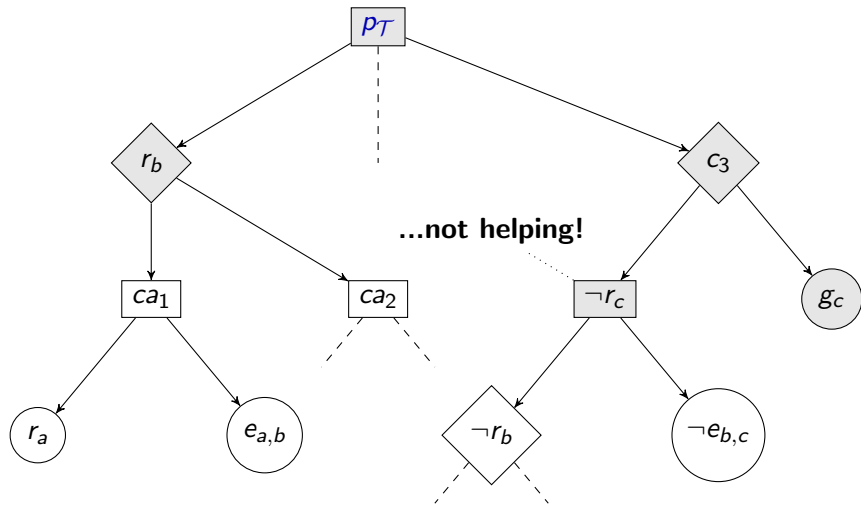
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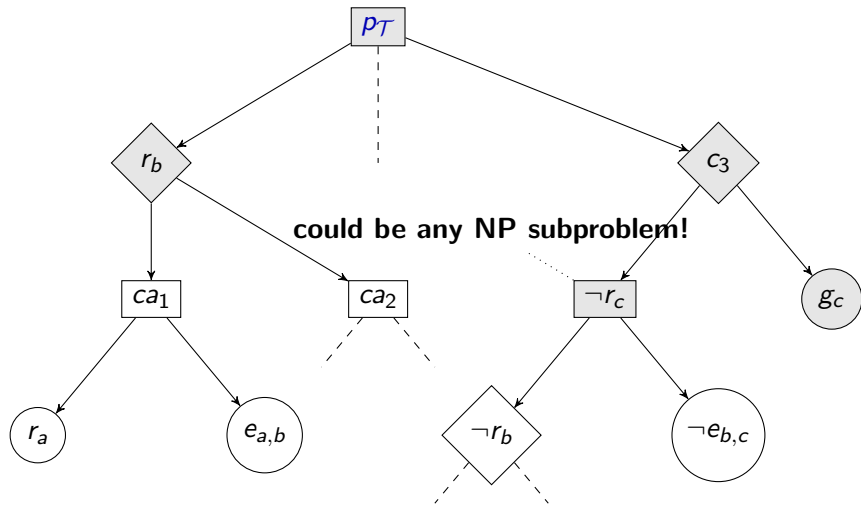
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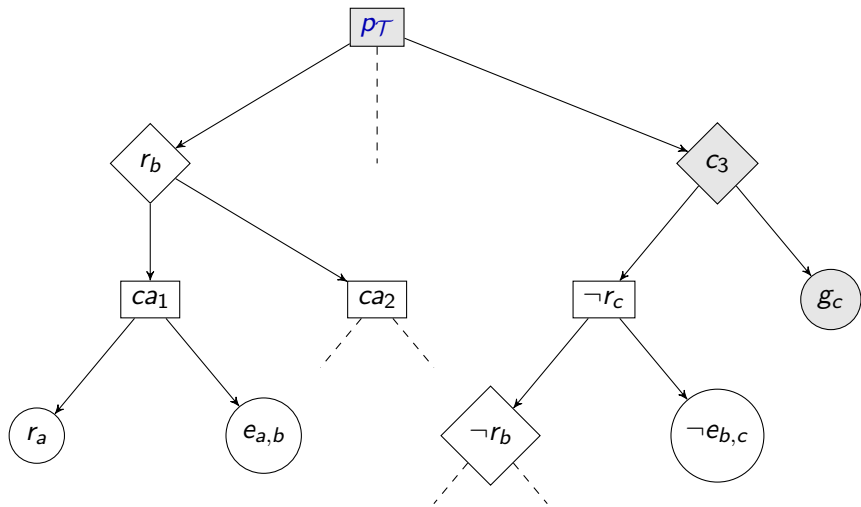
Justifications

- ▶ 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.

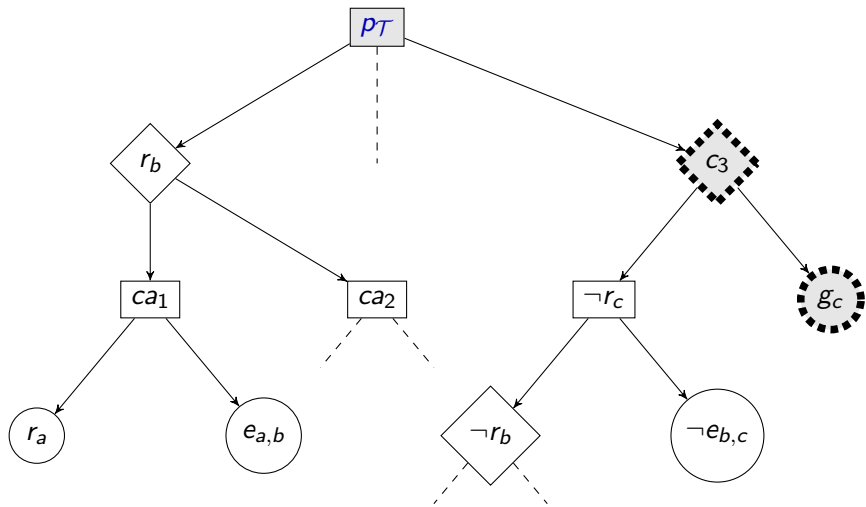
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- ▶ Intuitively, a literal is *justified* given a partial assignment if there exists a (recursive) explanation why it must hold in terms of true open literals.
- ▶ If a literal is justified in a partial assignment, then there exists a model of Δ in 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.

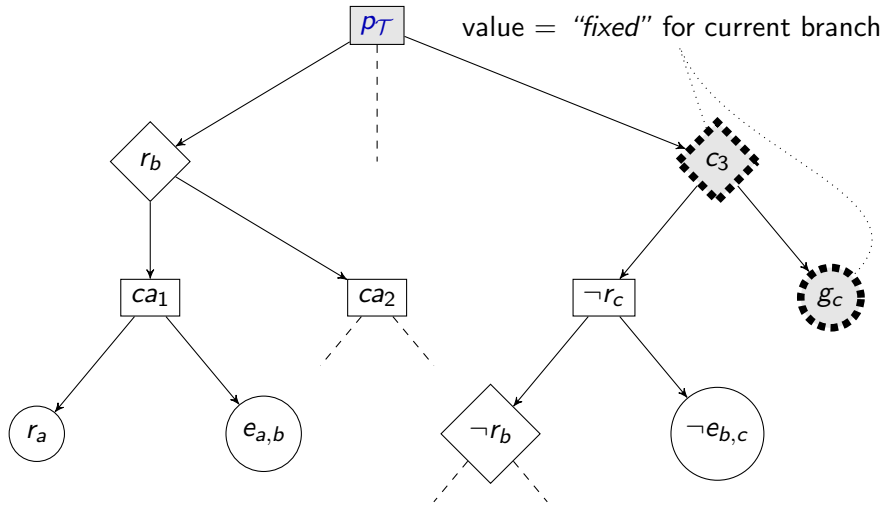
Searching assignment \rightarrow searching *justification*



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Searching assignment → searching *justification*



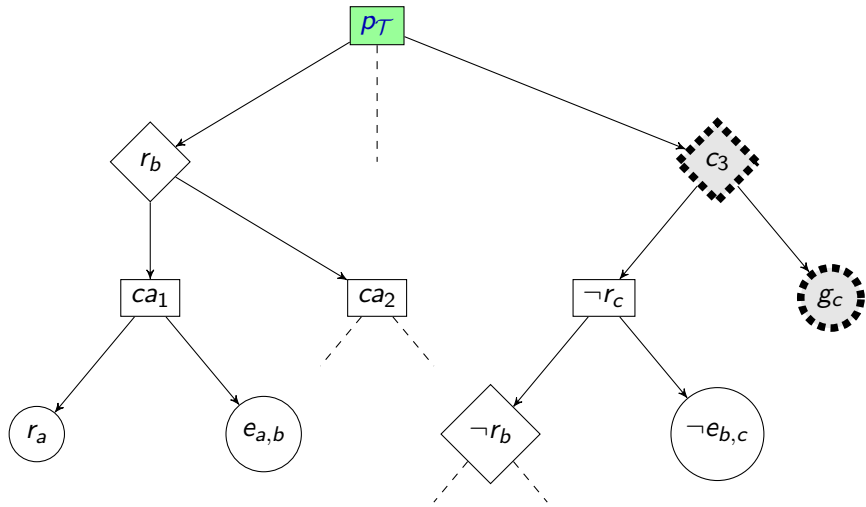
Relevance

Definition

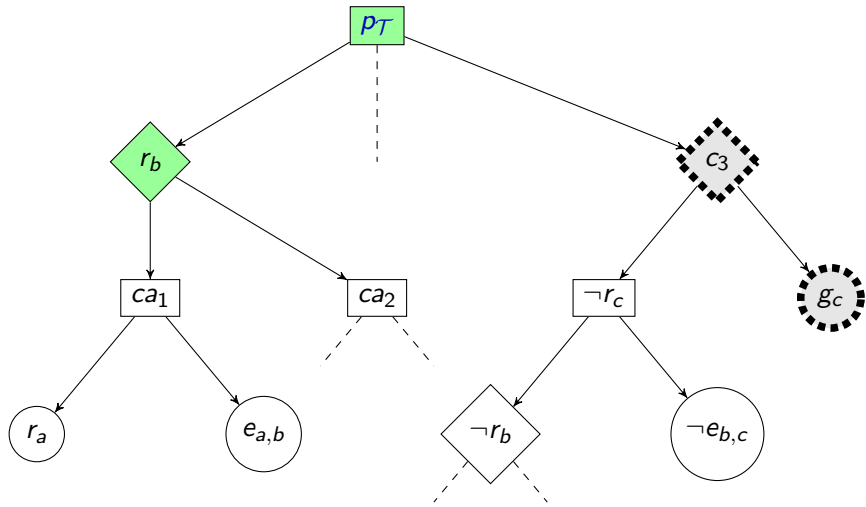
Given a PC(ID) theory $\mathcal{T} = \{p_{\mathcal{T}}, \Delta\}$ and a partial interpretation \mathcal{I} , we inductively define the set of relevant literals, denoted $\mathcal{R}_{\mathcal{T}, \mathcal{I}}$, as follows

- ▶ $p_{\mathcal{T}}$ 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.

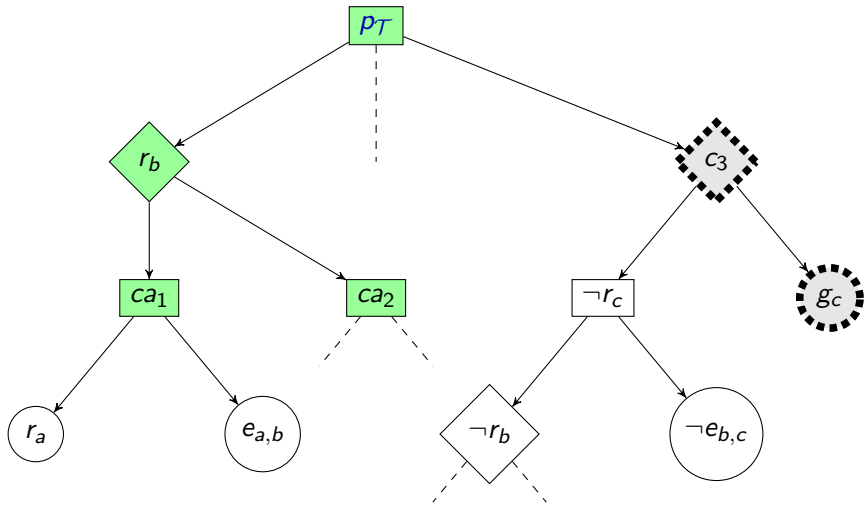
Relevant \approx can help justify p_T



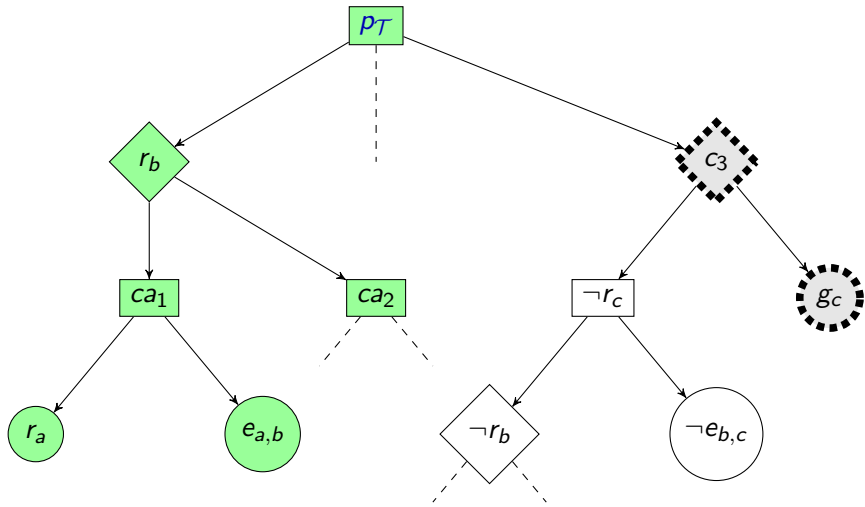
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Relevant \approx can help justify p_T



Adjusting the Solver

- ▶ Decide only on **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

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 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.

Keeping track of relevant literals

- ▶ For each relevant literal (except p_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)

Keeping track of relevant literals

- ▶ For each relevant literal (except p_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)
- ▶ 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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- ▶ Problems from previous ASP competitions
- ▶ Solver = Minisatid, Heuristic = VSIDS
- ▶ 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%

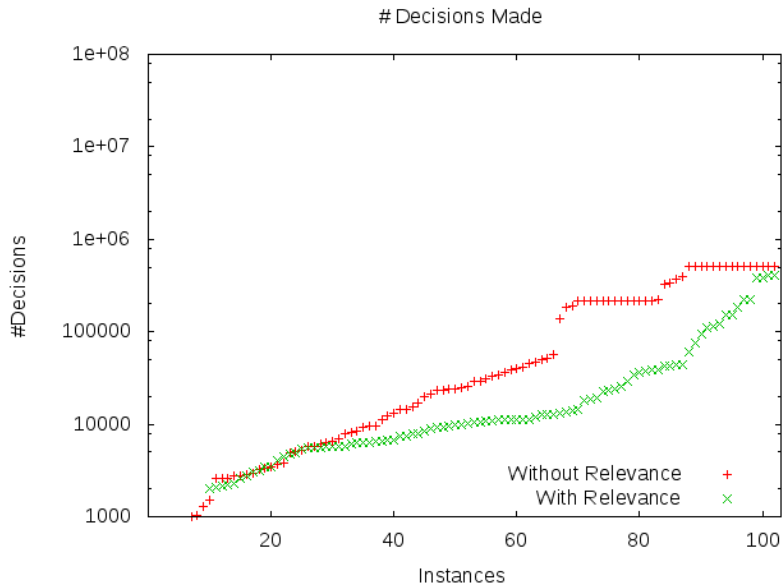
Experiment Setup (2)

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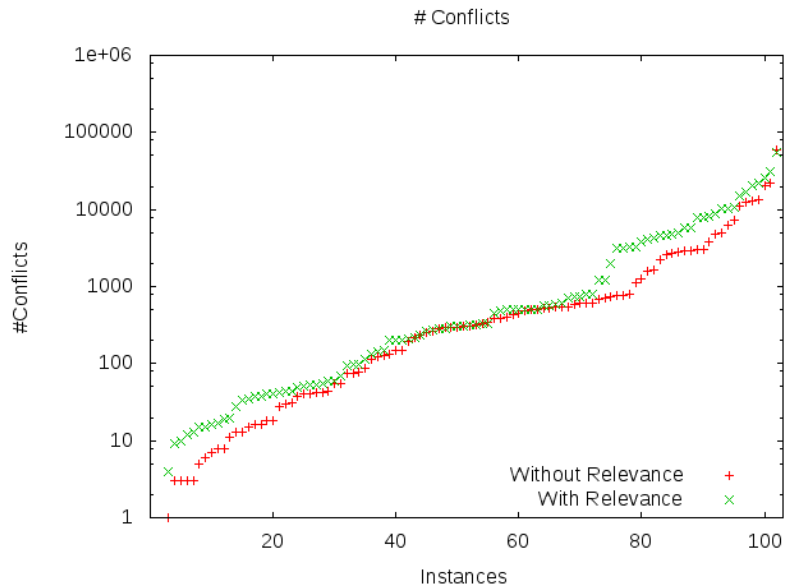
Experiment Setup (2)

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- ▶ Solver = Minisatid, Heuristic = VSIDS
- ▶ Measuring
 - ▶ Number of decisions (#)
 - ▶ Number of conflicts (#)

Experimental Results (2)



Experimental Results (2)



Take-away messages

- ▶ Exploit problem hierarchy using *Relevance*

Take-away messages

- ▶ Exploit problem hierarchy using **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?