

Conflict Driven Clause Learning

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Modern SAT Solvers: Conflict Driven Clause Learning (CDCL)

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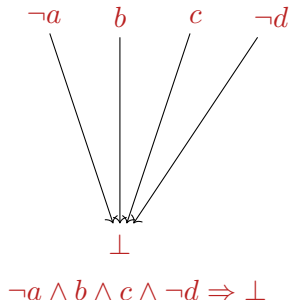
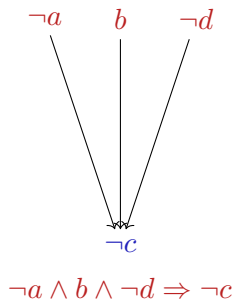
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- **Can be seen as a CP Solver (Search, propagation) augmented by clause learning**
- But also :
 - Activity-based branching
 - Lazy data structures (2-Watched Literals)
 - Clause Database Reduction
 - Simplifications
 - Restarts
 - ...

Exercise: Propose a filtering algorithm for clauses. The algorithm takes as input a clause and has access (read and write) for the variables domains.

Unit Propagation

Given a clause C of arity n . If $n - 1$ literals are false then set the last one to be true.

Example: $(a \vee \neg b \vee \neg c \vee d)$



Two Watched Literals

- Unit propagation is implemented with an “intelligent” data structure called Two-watched literals
- Observe first that propagation happens only in two cases:
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- If a literal watching a clause C becomes *false*, look for replacement. If no replacement found, then perform propagation

Implication Graph

	f		

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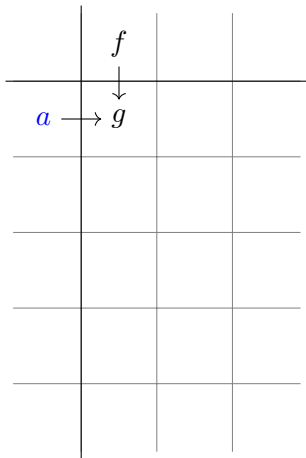
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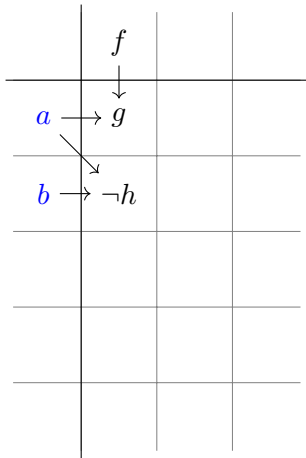
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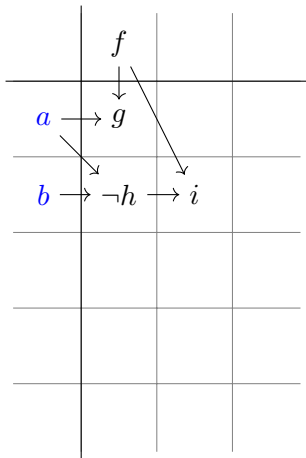
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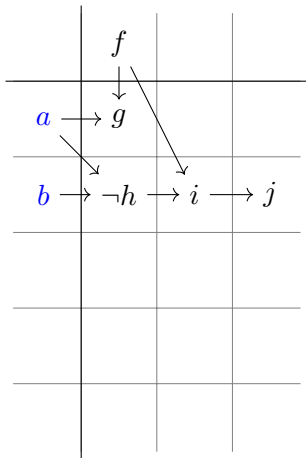
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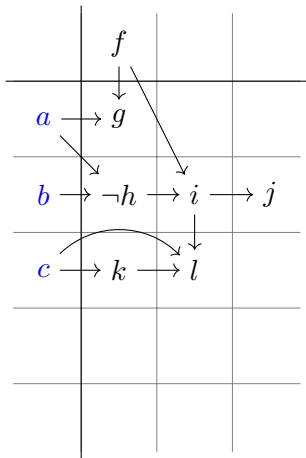
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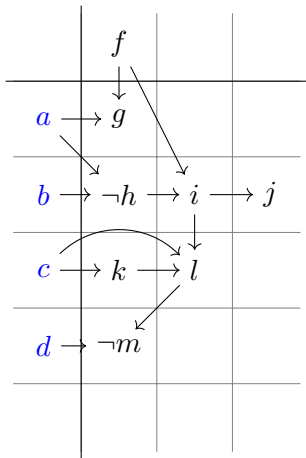
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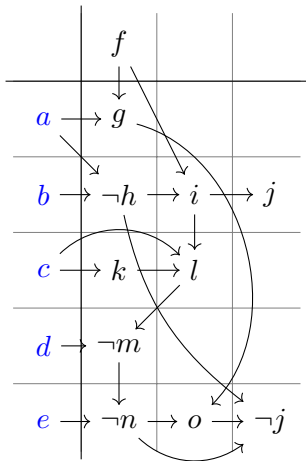
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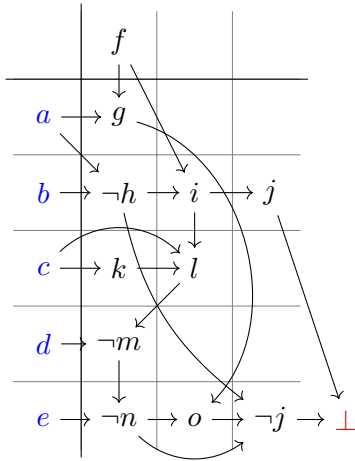
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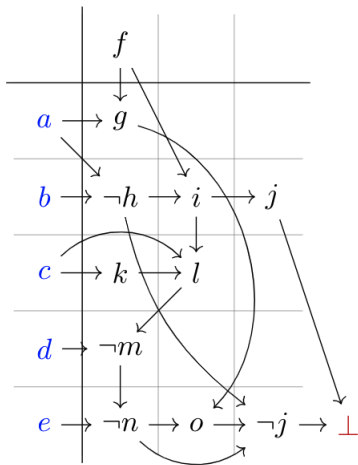
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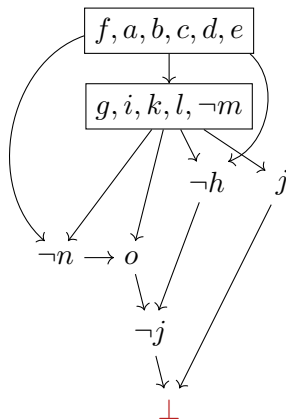
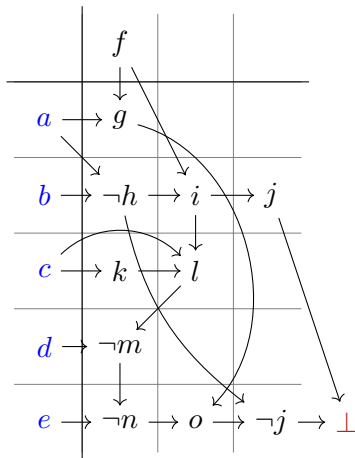
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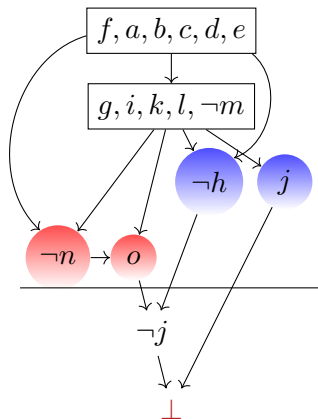
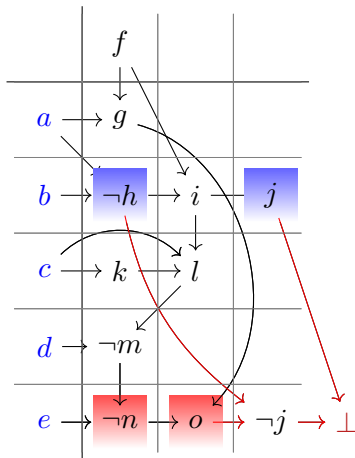
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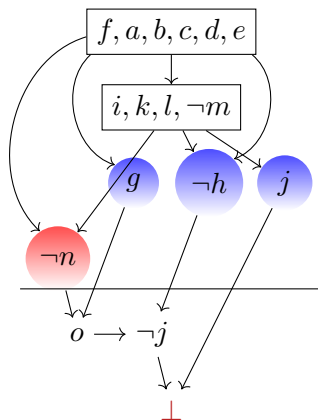
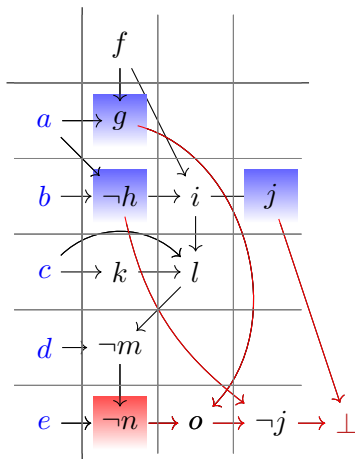
Conflict Analysis



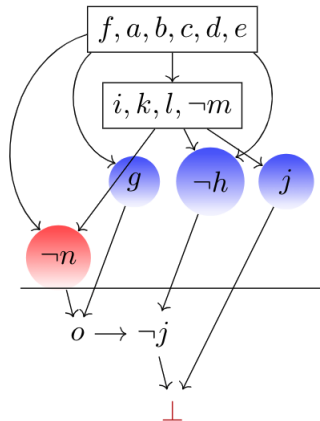
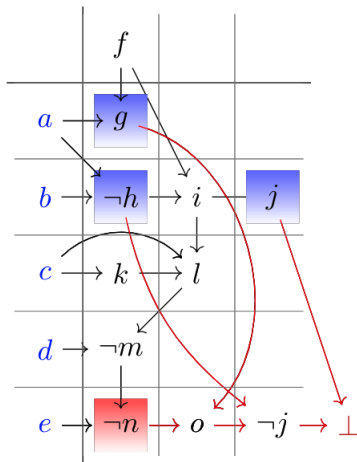
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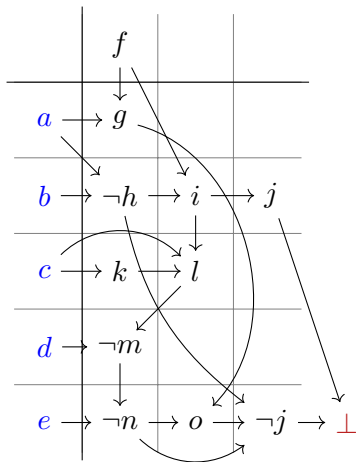
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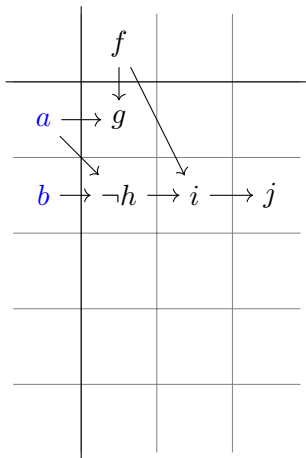
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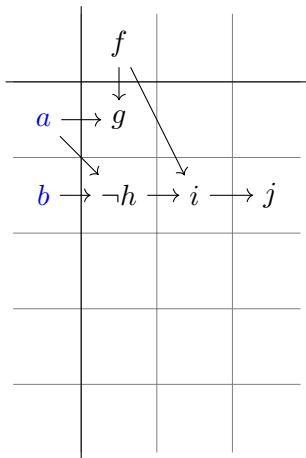
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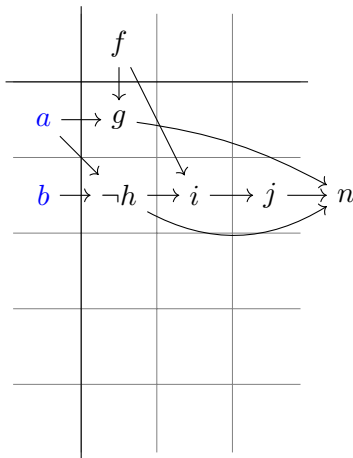


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Learning and Backjumping

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- When there is only one literal *ui*p propagated in the last level in the current explanation, learn the associated new clause C ,

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- When there is only one literal uip propagated in the last level in the current explanation, learn the associated new clause C , backjump (to the last level of propagated literals in C),

Learning and Backjumping

- Definition: Explaining a failure: $l_1 \wedge \dots \wedge l_n \rightarrow \perp$ where $\neg l_1 \vee \dots \vee \neg l_n$ is the clause triggering failure
- Definition: Explaining a propagation of l : $l_1 \wedge \dots \wedge l_n \rightarrow l$ where $\neg l_1 \vee \dots \vee \neg l_n \vee \neg l$ is the triggering clause
- At each conflict learn a new clause as following:
- Start with the explanation from the clause triggering failure in the form of $l_1 \wedge \dots \wedge l_n \rightarrow \perp$ and let it be the initial explanation
- While there is more than a literal propagated in the last level in the current explanation, replace it with its explanation from the triggering clause
- When there is only one literal uip propagated in the last level in the current explanation, learn the associated new clause C , backjump (to the last level of propagated literals in C), propagate $\neg uip$ via the new clause,

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- When there is only one literal uip propagated in the last level in the current explanation, learn the associated new clause C , backjump (to the last level of propagated literals in C), propagate $\neg uip$ via the new clause, and continue the exploration

Boosting Search through Randomization and Restarts [Gomes et al., 1998]

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Heavy-tail phenomena (SAT and CP)

At any time during the experiment there is a non-negligible probability of hitting a problem that requires exponentially more time to solve than any that has been encountered before.

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- Randomization: breaking ties, random decision between k best choices, ...
- Restarts: Geometric/Luby

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SAT Solvers (Few examples)

- MiniSat: <http://minisat.se/>
- Glucose: <http://www.labri.fr/perso/lsimon/glucose/>
- Lingeling <http://fmv.jku.at/lingeling>
- Any Solver by Armin Biere
<http://fmv.jku.at/software/index.html>
- Any winner from past and future SAT competitions:
<https://www.satcompetition.org/>

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