Complete and Efficient DRAT Proof Checking

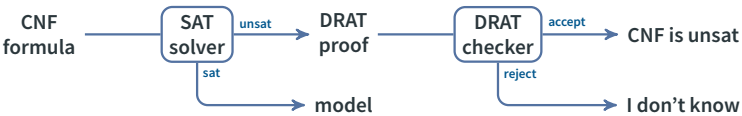
Adrián Rebola-Pardo, Luís Cruz-Filipe

TU Wien, University of Southern Denmark

FMCAD 2018
Austin, USA
November 2nd, 2018

Supported by FWF W1255-N23 and Microsoft Research through its PhD Programme

SAT solving and DRAT proofs

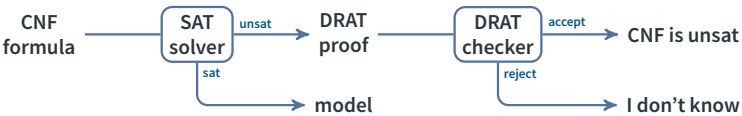


SAT solving and DRAT proofs

DRAT proof sequence of clause introductions and deletions

- i: C — C must be a RUP or RAT clause
- d: C — always allowed
- i: $\square$ — finishes the proof

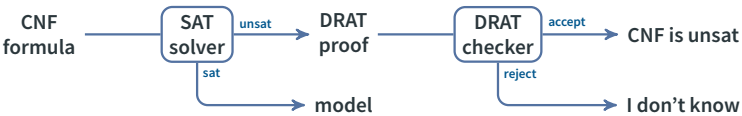
SAT solving and DRAT proofs



DRAT proof sequence of clause introductions and deletions

- i: C — C must be a RUP or RAT clause
- d: C — always allowed
- i: $\square$ — finishes the proof

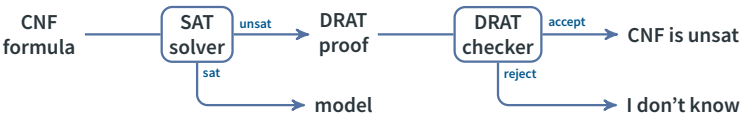
SAT solving and DRAT proofs



DRAT proof sequence of clause introductions and deletions

- i: C — C must be a RUP or RAT clause
- d: C — always allowed
- i: $\square$ — finishes the proof

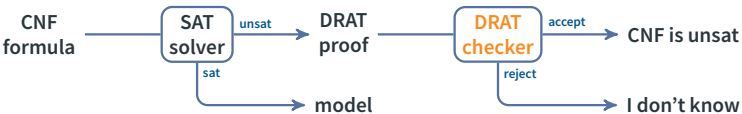
SAT solving and DRAT proofs



DRAT proof sequence of clause introductions and deletions

- **i:** C — C must be a RUP or RAT clause
- **d:** C — always allowed
- **i:** $\square$ — finishes the proof

SAT solving and DRAT proofs

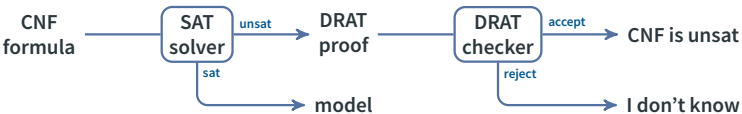


DRAT proof sequence of clause introductions and deletions

- i: C — C must be a RUP or RAT clause
- d: C — always allowed
- i: $\square$ — finishes the proof

DRAT checker checks that each inference is correct

SAT solving and DRAT proofs



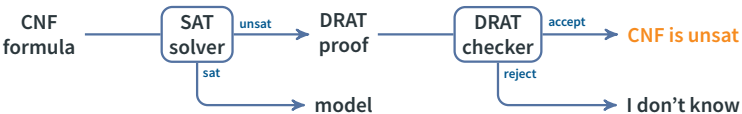
DRAT proof sequence of clause introductions and deletions

- **i:** C — C must be a RUP or RAT clause
- **d:** C — always allowed
- **i:** $\square$ — finishes the proof

DRAT checker checks that each inference is correct

RUP / RAT introduction and clause deletion are satisfiabilty-preserving

SAT solving and DRAT proofs



DRAT proof sequence of clause introductions and deletions

- **i:** C — C must be a RUP or RAT clause
- **d:** C — always allowed
- **i:** $\square$ — finishes the proof

DRAT checker checks that each inference is correct

RUP / RAT introduction and clause deletion are satisfiabilty-preserving

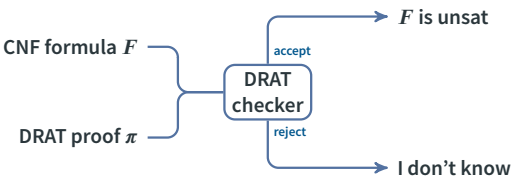
if $\square$ is derived, then the input formula is unsatisfiable

What I talk about when I talk about checking

DRAT checker checks that each inference is correct

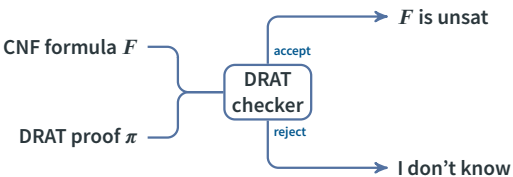
What I talk about when I talk about checking

DRAT checker checks that each inference is correct



What I talk about when I talk about checking

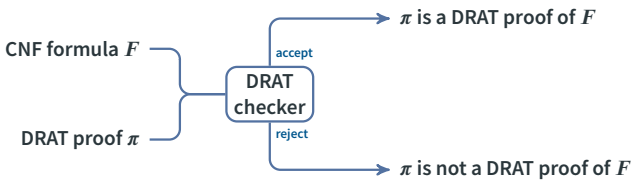
DRAT checker checks that each inference is correct



This criterion is problematic: F **unsat,** $\pi =$ `covfefe` $\Rightarrow$ **accept**

What I talk about when I talk about checking

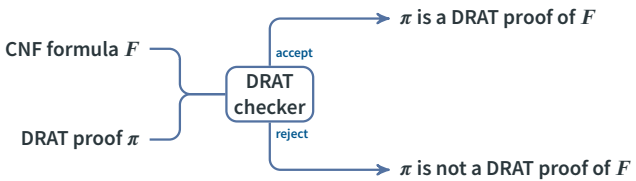
DRAT checker checks that each inference is correct



This criterion is problematic: F **unsat,** $\pi =$ `covfefe` $\Rightarrow$ **accept**

What I talk about when I talk about checking

DRAT checker checks that each inference is correct



This criterion is problematic: F unsat, π = `covfefe` ⇒ accept

Problem state-of-the-art DRAT checkers decide something slightly different from DRAT correctness

Two flavors of DRAT

Proof system specification of *correct* refutations

Two flavors of DRAT

Proof system specification of *correct* refutations

Sound proof system if a correct refutation of F exists, then F is unsatisfiable

Refutations are correct with respect to a proof system

Two flavors of DRAT

Proof system specification of *correct* refutations

Sound proof system if a correct refutation of F exists, then F is unsatisfiable

Refutations are correct **with respect to a proof system**

specified DRAT

[Wetzler, Heule, Hunt '14]

operational DRAT

`drat-trim`, `gratgen`

Two flavors of DRAT

Proof system specification of *correct* refutations

Sound proof system if a correct refutation of F exists, then F is unsatisfiable

Refutations are correct **with respect to a proof system**

specified DRAT

[Wetzler, Heule, Hunt '14]

all deletions are applied

operational DRAT

`drat-trim`, `gratgen`

unit deletions are ignored

Two flavors of DRAT

Proof system specification of *correct* refutations

Sound proof system if a correct refutation of F exists, then F is unsatisfiable

Refutations are correct **with respect to a proof system**

specified DRAT

[Wetzler, Heule, Hunt '14]

all deletions are applied

sound proof system

operational DRAT

`drat-trim`, `gratgen`

unit deletions are ignored

sound proof system

Two flavors of DRAT

Proof system specification of *correct* refutations

Sound proof system if a correct refutation of F exists, then F is unsatisfiable

Refutations are correct **with respect to a proof system**

specified DRAT

[Wetzler, Heule, Hunt '14]

all deletions are applied

sound proof system

operational DRAT

`drat-trim`, `gratgen`

unit deletions are ignored

sound proof system

Discrepancies exist [Rebola-Pardo, Biere '18] sDRAT-correct proofs that are oDRAT-incorrect, and oDRAT-correct proofs that are sDRAT-incorrect

Why two flavors

Why operational DRAT? **The methods used in state-of-the-art DRAT checkers do not work when unit clause deletions occur in the input proof**

ignore unit clause deletions

Why two flavors

Why operational DRAT? The methods used in state-of-the-art DRAT checkers do not work when unit clause deletions occur in the input proof

ignore unit clause deletions

Why specified DRAT? generating proofs for inprocessing techniques becomes very complicated [Rebola-Pardo, Biere '18]

RAT introduction depends on the absence of clauses.

Why two flavors

Why operational DRAT? The methods used in state-of-the-art DRAT checkers do not work when unit clause deletions occur in the input proof

ignore unit clause deletions

Why specified DRAT? generating proofs for inprocessing techniques becomes very complicated [Rebola-Pardo, Biere '18]

RAT introduction depends on the absence of clauses.

Contributions

- Can we check sDRAT as efficiently as oDRAT?
- How often do discrepancies occur in practice?

Why two flavors

Why operational DRAT? The methods used in state-of-the-art DRAT checkers do not work when unit clause deletions occur in the input proof

ignore unit clause deletions

Why specified DRAT? generating proofs for inprocessing techniques becomes very complicated [Rebola-Pardo, Biere '18]

RAT introduction depends on the absence of clauses.

Contributions

- Can we check sDRAT as efficiently as oDRAT? Very likely
- How often do discrepancies occur in practice?

Why two flavors

Why operational DRAT? The methods used in state-of-the-art DRAT checkers do not work when unit clause deletions occur in the input proof

ignore unit clause deletions

Why specified DRAT? generating proofs for inprocessing techniques becomes very complicated [Rebola-Pardo, Biere '18]

RAT introduction depends on the absence of clauses.

Contributions

- Can we check sDRAT as efficiently as oDRAT? Very likely
- How often do discrepancies occur in practice? Quite a lot

Experimental evaluation

Experimental setting

Questions

- Can we check sDRAT as efficiently as oDRAT?
- How often do discrepancies occur in practice?

Experimental setting

Questions

- **Can we check sDRAT as efficiently as oDRAT?**
- **How often do discrepancies occur in practice?**

drat-trim ***de facto* standard tool for DRAT proof checking** [Heule '16]

many code optimizations, very hard to modify

Experimental setting

Questions

- **Can we check sDRAT as efficiently as oDRAT?**
- **How often do discrepancies occur in practice?**

drat-trim ***de facto* standard tool for DRAT proof checking** [Heule '16]
many code optimizations, very hard to modify

rupee **can perform sDRAT and oDRAT checking with minimal code changes**

Experimental setting

Questions

- **Can we check sDRAT as efficiently as oDRAT?**
- **How often do discrepancies occur in practice?**

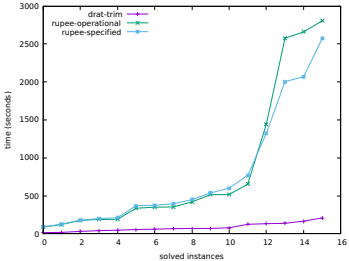
drat-trim ***de facto*** **standard tool for DRAT proof checking** [Heule '16]
many code optimizations, very hard to modify

rupee **can perform sDRAT and oDRAT checking with minimal code changes**

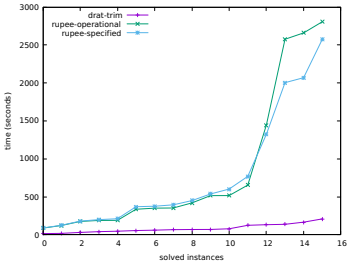
Benchmarks **11 instances from SAT Competition 2017**

Solvers `COMinisatPS_Pulsar`, `glucose-4.1`, `Maple_LCM_Dist`, `cadical-sc17`

Experimental results



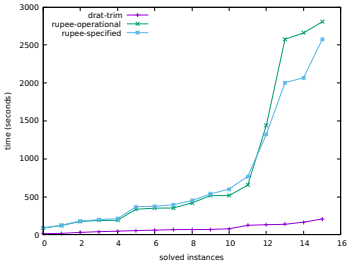
Experimental results



`rupee` **performs about an order of magnitude worse than** `drat-trim`

probably due to code optimization and core-first propagation

Experimental results



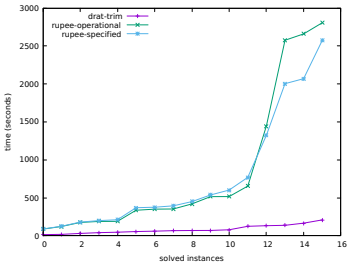
`rupee` **performs about an order of magnitude worse than** `drat-trim`

probably due to code optimization and core-first propagation

`rupee` **in sDRAT mode performs comparably to** `rupee` **in oDRAT mode**

no observable overhead due to unit clause deletion

Experimental results



`rupee` **performs about an order of magnitude worse than** `drat-trim`

probably due to code optimization and core-first propagation

`rupee` **in sDRAT mode performs comparably to** `rupee` **in oDRAT mode**

no observable overhead due to unit clause deletion

All proofs generated by `cadical-sc17` **are correct for both sDRAT and oDRAT. For the other 3 solvers, 8 out of 11 proofs were incorrect as sDRAT and correct as oDRAT.**

probably due to the CDCL proof generation method inherited from `minisat`

Why are unit deletions ignored?

State-of-the-art DRAT checking

$$x_1$$
$$\overline{x_1}\ x_2$$
$$\overline{x_1}\ \overline{x_2}\ x_3$$
$$\overline{x_1}\ \overline{x_3}\ x_4$$

$$x_5\ x_6$$
$$\overline{x_2}\ \overline{x_5}\ x_7$$
$$\overline{x_1}\ \overline{x_5}\ x_6$$
$$x_4\ \overline{x_5}\ \overline{x_6}$$

$$\overline{x_3}\ \overline{x_6}\ x_8$$
$$x_3\ \overline{x_4}\ \overline{x_6}$$
$$x_5\ \overline{x_8}$$
$$\overline{x_3}\ x_9\ x_{10}$$

$$\overline{x_4}\ \overline{x_9}\ x_{10}$$
$$x_9\ \overline{x_{10}}$$
$$x_7\ \overline{x_9}$$
$$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$$

State-of-the-art DRAT checking

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$
$\overline{x_1}\ x_2$	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5

i: x_9

i: □

State-of-the-art DRAT checking

x_1	$x_5\, x_6$	$\overline{x_3}\, \overline{x_6}\, x_8$	$\overline{x_4}\, \overline{x_9}\, x_{10}$
$\overline{x_1}\, x_2$	$\overline{x_2}\, \overline{x_5}\, x_7$	$x_3\, \overline{x_4}\, \overline{x_6}$	$x_9\, \overline{x_{10}}$
$\overline{x_1}\, \overline{x_2}\, x_3$	$\overline{x_1}\, \overline{x_5}\, x_6$	$x_5\, \overline{x_8}$	$x_7\, \overline{x_9}$
$\overline{x_1}\, \overline{x_3}\, x_4$	$x_4\, \overline{x_5}\, \overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\, \overline{x_8}\, \overline{x_9}\, \overline{x_{10}}$

i: x_5

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\overline{x_5}$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\quad \overline{x_5}\ x_1$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\quad \overline{x_5}\ x_1\ x_2$

i: x_9

i: □

C **is a reverse unit propagation (RUP) clause in** ***F*** **whenever** $F \wedge \overline{C}$ **reaches a conflict by unit propagation**

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3$

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4$

i: x_9

i: □

C **is a reverse unit propagation (RUP) clause in** ***F*** **whenever** $F \wedge \overline{C}$ **reaches a conflict by unit propagation**

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6$

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$
$\overline{x_1}\ x_2$	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot$

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7$

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}$

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot\ \Rightarrow$ RUP

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot\ \Rightarrow$ RUP

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot\ \Rightarrow$ RUP

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5
x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot \Rightarrow$ RUP

i: $\square$ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5
x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot \Rightarrow$ RUP

i: $\square$ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot \Rightarrow$ RUP

i: $\square$ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

i: x_5 $\overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot$ ⇒ RUP

i: x_9 $\overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot$ ⇒ RUP

i: □ $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$ ⇒ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot\ \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot\ \Rightarrow$ RUP

i: $\square$ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot\ \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot \quad \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot \quad \Rightarrow$ RUP

i: $\square$ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \quad \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot \quad \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot \quad \Rightarrow$ RUP

i: $\square$ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \quad \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot \quad \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot \quad \Rightarrow$ RUP

i: $\square$ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \quad \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

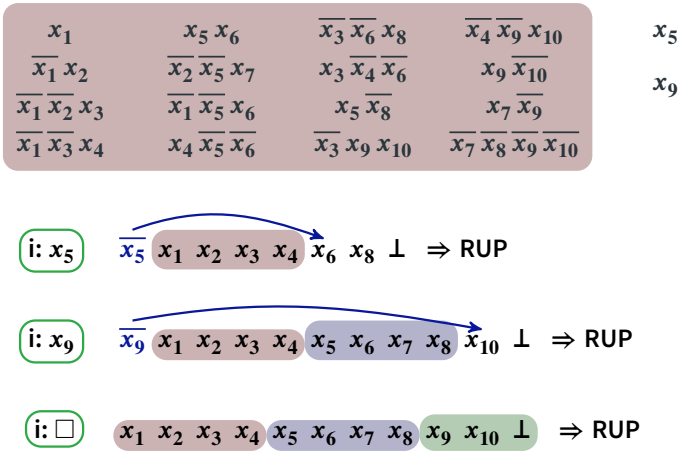
i: x_5 $\quad \overline{x_5}\ x_1\ x_2\ x_3\ x_4\ x_6\ x_8\ \bot \Rightarrow$ RUP

i: x_9 $\quad \overline{x_9}\ x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_{10}\ \bot \Rightarrow$ RUP

i: □ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \Rightarrow$ RUP

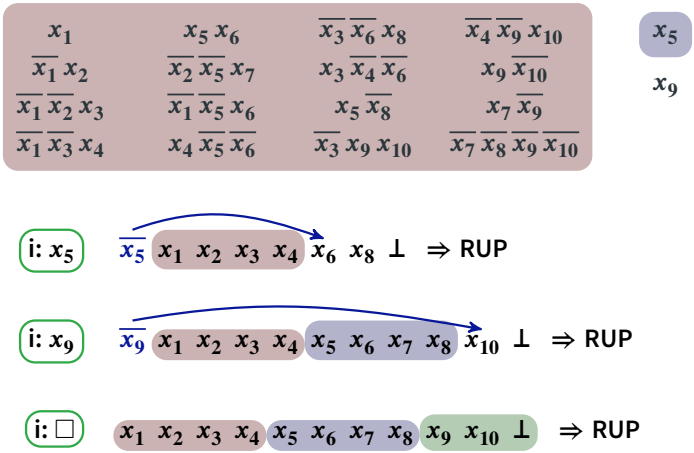
C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking



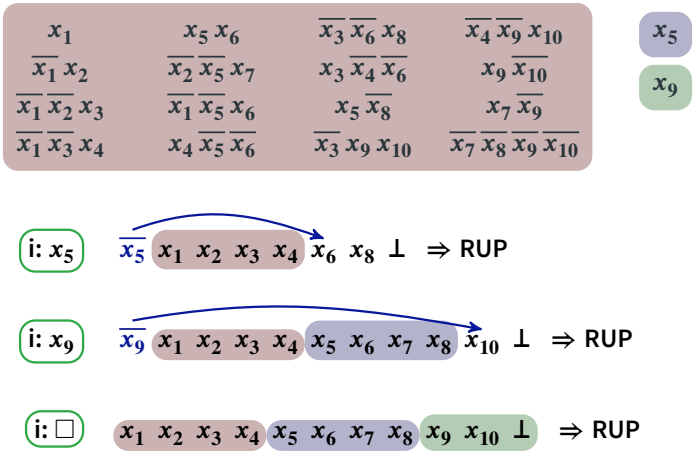
C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

State-of-the-art DRAT checking

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$
$\overline{x_1}\, x_2$	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

i: x_5

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1 $\quad$ $\overline{x_1}\ x_2$ $\quad$ $\overline{x_1}\ \overline{x_2}\ x_3$ $\quad$ $\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$ $\quad$ $\overline{x_2}\ \overline{x_5}\ x_7$ $\quad$ $\overline{x_1}\ \overline{x_5}\ x_6$ $\quad$ $x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$ $\quad$ $x_3\ \overline{x_4}\ \overline{x_6}$ $\quad$ $x_5\ \overline{x_8}$ $\quad$ $\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$ $\quad$ $x_9\ \overline{x_{10}}$ $\quad$ $x_7\ \overline{x_9}$ $\quad$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_1

i: x_5

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2$

i: x_5

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3$

i: x_5

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

i: x_9

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations **trace preprocessing and backwards checking**

State-of-the-art DRAT checking

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$	x_5
$\overline{x_1}\ x_2$	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$	
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$	
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations **trace preprocessing and backwards checking**

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5
x_9

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5
x_9

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations **trace preprocessing and backwards checking**

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9$

i: $\square$

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1 | $\overline{x_1}\ x_2$ | $\overline{x_1}\ \overline{x_2}\ x_3$ | $\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$ | $\overline{x_2}\ \overline{x_5}\ x_7$ | $\overline{x_1}\ \overline{x_5}\ x_6$ | $x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$ | $x_3\ \overline{x_4}\ \overline{x_6}$ | $x_5\ \overline{x_8}$ | $\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$ | $x_9\ \overline{x_{10}}$ | $x_7\ \overline{x_9}$ | $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5 | x_9

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}$

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5
x_9

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

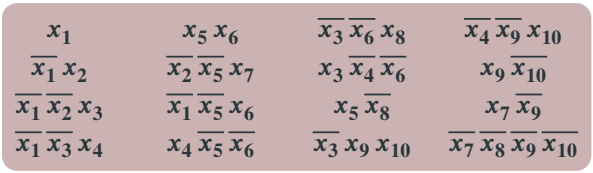
$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations **trace preprocessing and backwards checking**

State-of-the-art DRAT checking



$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

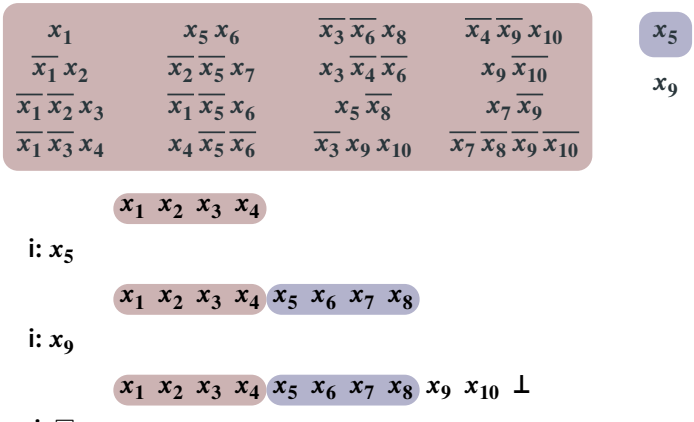
$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

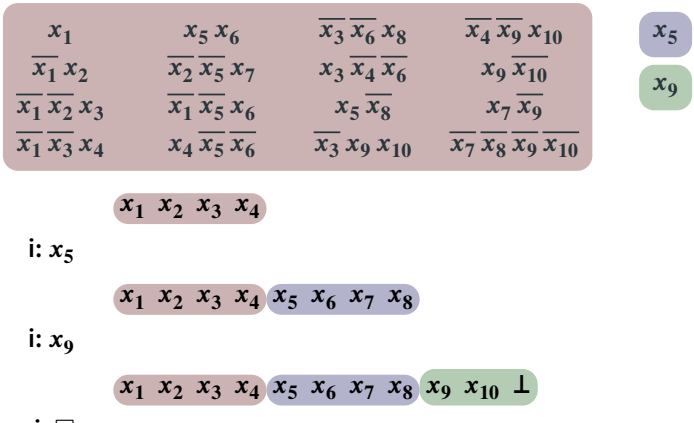
State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

x_9

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

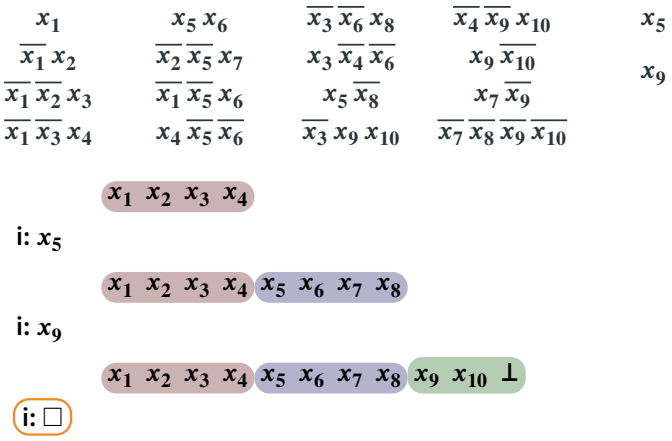
$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

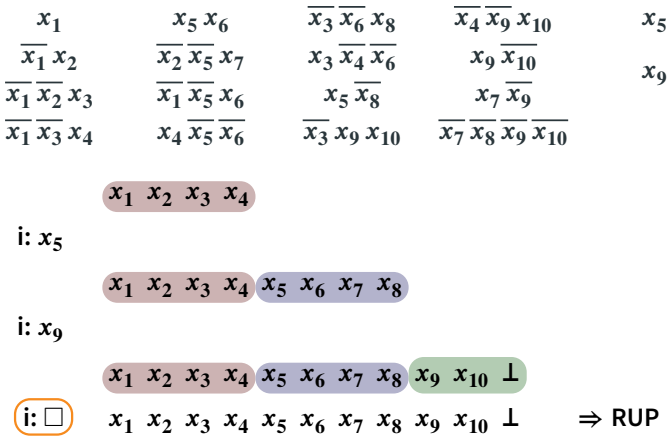
State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

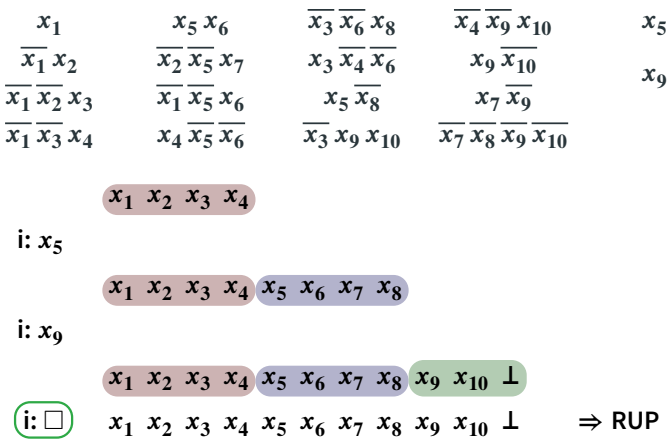
State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

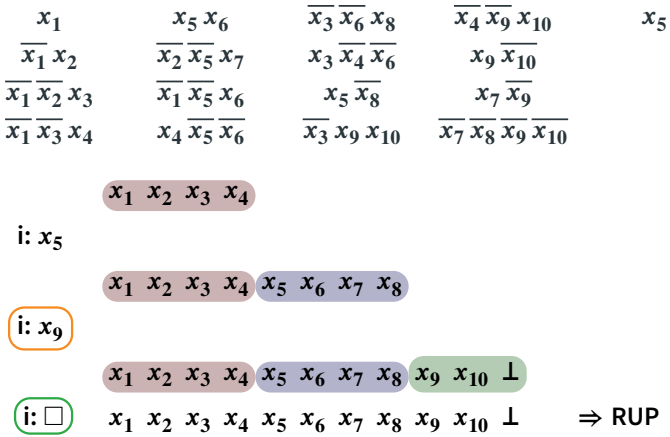
State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1 $\quad$ $x_5\,x_6$ $\quad$ $\overline{x_3}\,\overline{x_6}\,x_8$ $\quad$ $\overline{x_4}\,\overline{x_9}\,x_{10}$ $\quad$ x_5

$\overline{x_1}\,x_2$ $\quad$ $\overline{x_2}\,\overline{x_5}\,x_7$ $\quad$ $x_3\,\overline{x_4}\,\overline{x_6}$ $\quad$ $x_9\,\overline{x_{10}}$

$\overline{x_1}\,\overline{x_2}\,x_3$ $\quad$ $\overline{x_1}\,\overline{x_5}\,x_6$ $\quad$ $x_5\,\overline{x_8}$ $\quad$ $x_7\,\overline{x_9}$

$\overline{x_1}\,\overline{x_3}\,x_4$ $\quad$ $x_4\,\overline{x_5}\,\overline{x_6}$ $\quad$ $\overline{x_3}\,x_9\,x_{10}$ $\quad$ $\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $\quad$ $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

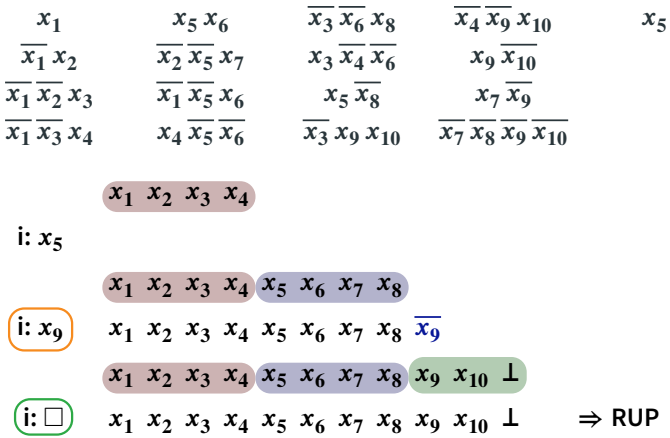
$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □ $\quad$ $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$ $\quad$ ⇒ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ \overline{x_9}\ x_{10}\ \bot$

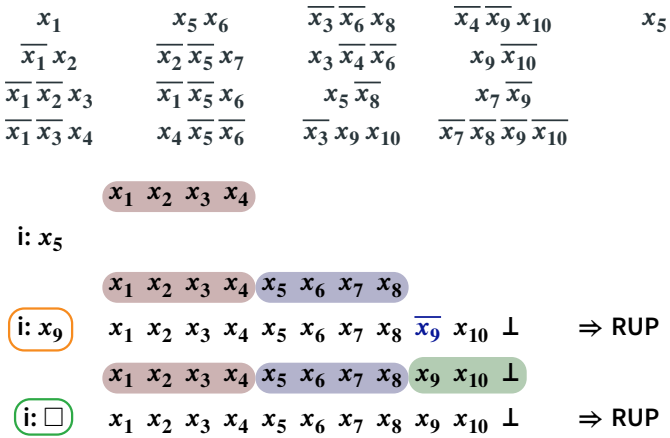
$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \quad \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking



C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1 $\quad$ $x_5\ x_6$ $\quad$ $\overline{x_3}\ \overline{x_6}\ x_8$ $\quad$ $\overline{x_4}\ \overline{x_9}\ x_{10}$ $\quad$ x_5

$\overline{x_1}\ x_2$ $\quad$ $\overline{x_2}\ \overline{x_5}\ x_7$ $\quad$ $x_3\ \overline{x_4}\ \overline{x_6}$ $\quad$ $x_9\ \overline{x_{10}}$

$\overline{x_1}\ \overline{x_2}\ x_3$ $\quad$ $\overline{x_1}\ \overline{x_5}\ x_6$ $\quad$ $x_5\ \overline{x_8}$ $\quad$ $x_7\ \overline{x_9}$

$\overline{x_1}\ \overline{x_3}\ x_4$ $\quad$ $x_4\ \overline{x_5}\ \overline{x_6}$ $\quad$ $\overline{x_3}\ x_9\ x_{10}$ $\quad$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $\quad$ $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ \overline{x_9}\ x_{10}\ \bot$ $\quad \Rightarrow$ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □ $\quad$ $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$ $\quad \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ \overline{x_9}\ x_{10}\ \bot$ $\quad \Rightarrow$ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$ $\quad \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5 $x_1\ x_2\ x_3\ x_4$

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ \overline{x_9}\ x_{10}\ \bot$ ⇒ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □ $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$ ⇒ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5 $x_1\ x_2\ x_3\ x_4\ \overline{x_5}$

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ \overline{x_9}\ x_{10}\ \bot$ $\Rightarrow$ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □ $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$ $\Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5 $x_1\ x_2\ x_3\ x_4\ \overline{x_5}\ x_6\ x_8\ \bot$

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ \overline{x_9}\ x_{10}\ \bot$ $\Rightarrow$ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: $\square$ $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$ $\Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

$$
\begin{array}{cccc}
x_1 & x_5\, x_6 & \overline{x_3}\,\overline{x_6}\, x_8 & \overline{x_4}\,\overline{x_9}\, x_{10} \\
\overline{x_1}\, x_2 & \overline{x_2}\,\overline{x_5}\, x_7 & x_3\,\overline{x_4}\,\overline{x_6} & x_9\,\overline{x_{10}} \\
\overline{x_1}\,\overline{x_2}\, x_3 & \overline{x_1}\,\overline{x_5}\, x_6 & x_5\,\overline{x_8} & x_7\,\overline{x_9} \\
\overline{x_1}\,\overline{x_3}\, x_4 & x_4\,\overline{x_5}\,\overline{x_6} & \overline{x_3}\, x_9\, x_{10} & \overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}
\end{array}
$$

$x_1\ x_2\ x_3\ x_4$

i: x_5 $\quad x_1\ x_2\ x_3\ x_4\ \overline{x_5}\ x_6\ x_8\ \bot \quad \Rightarrow$ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ \overline{x_9}\ x_{10}\ \bot \quad \Rightarrow$ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \quad \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

State-of-the-art DRAT checking

$$
\begin{array}{cccc}
x_1 & x_5\, x_6 & \overline{x_3}\,\overline{x_6}\, x_8 & \overline{x_4}\,\overline{x_9}\, x_{10} \\
\overline{x_1}\, x_2 & \overline{x_2}\,\overline{x_5}\, x_7 & x_3\,\overline{x_4}\,\overline{x_6} & x_9\,\overline{x_{10}} \\
\overline{x_1}\,\overline{x_2}\, x_3 & \overline{x_1}\,\overline{x_5}\, x_6 & x_5\,\overline{x_8} & x_7\,\overline{x_9} \\
\overline{x_1}\,\overline{x_3}\, x_4 & x_4\,\overline{x_5}\,\overline{x_6} & \overline{x_3}\, x_9\, x_{10} & \overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}
\end{array}
$$

$x_1\ x_2\ x_3\ x_4$

i: x_5 $\quad x_1\ x_2\ x_3\ x_4\ \overline{x_5}\ x_6\ x_8\ \bot \quad \Rightarrow$ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9 $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ \overline{x_9}\ x_{10}\ \bot \quad \Rightarrow$ RUP

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot$

i: □ $\quad x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}\ \bot \quad \Rightarrow$ RUP

C is a reverse unit propagation (RUP) clause in F whenever $F \wedge \overline{C}$ reaches a conflict by unit propagation

Optimizations trace preprocessing and backwards checking

Unit clause deletion breaks stuff

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

i: x_5

d: $\overline{x_1}\ x_2$

i: x_9

i: $\square$

Unit clause deletion breaks stuff

x_1
$\overline{x_1}\ x_2$
$\overline{x_1}\ \overline{x_2}\ x_3$
$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$
$\overline{x_2}\ \overline{x_5}\ x_7$
$\overline{x_1}\ \overline{x_5}\ x_6$
$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$
$x_3\ \overline{x_4}\ \overline{x_6}$
$x_5\ \overline{x_8}$
$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$
$x_9\ \overline{x_{10}}$
$x_7\ \overline{x_9}$
$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

d: $\overline{x_1}\ x_2$

i: x_9

i: $\square$

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
$\overline{x_1}\, x_2$	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

d: $\overline{x_1}\, x_2$

i: x_9

i: $\square$

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
$\overline{x_1}\, x_2$	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$

d: $\overline{x_1}\, x_2$

i: x_9

i: $\square$

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
$\overline{x_1}\, x_2$	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\, x_2$

i: x_9

i: □

Unit clause deletion breaks stuff

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$	x_5
$\overline{x_1}\ x_2$	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$	
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$	
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

i: x_9

i: □

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\, x_2$

i: x_9

i: □

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\, x_2$

???

i: x_9

i: □

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\, x_2$

$x_1\ x_5\ x_6\ x_4\ x_3\ x_8$

i: x_9

i: $\square$

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\, \overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\, x_2$

$x_1\ x_5\ x_6\ x_4\ x_3\ x_8$

i: x_9

How do I find this?

How do I restore the trace during backwards checking?

i: □

Unit clause deletion breaks stuff

x_1

$\overline{x_1}\,\overline{x_2}\,x_3$

$\overline{x_1}\,\overline{x_3}\,x_4$

$x_5\,x_6$

$\overline{x_2}\,\overline{x_5}\,x_7$

$\overline{x_1}\,\overline{x_5}\,x_6$

$x_4\,\overline{x_5}\,\overline{x_6}$

$\overline{x_3}\,\overline{x_6}\,x_8$

$x_3\,\overline{x_4}\,\overline{x_6}$

$x_5\,\overline{x_8}$

$\overline{x_3}\,x_9\,x_{10}$

$\overline{x_4}\,\overline{x_9}\,x_{10}$

$x_9\,\overline{x_{10}}$

$x_7\,\overline{x_9}$

$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\,x_2$

$x_1\ x_5\ x_6\ x_4\ x_3\ x_8$

i: x_9

How do I find this?

How do I restore the trace during backwards checking?

i: □

Unit clause every literal but one is falsified by UP by the current formula

reason clauses are always unit clauses

How do we delete unit clauses

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
$\overline{x_1}\, x_2$	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\, x_2$

i: x_9

i: □

Unit clause deletion breaks stuff

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$	x_5
	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$	
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$	
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

i: x_9

i: □

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\, x_2$

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

i: $\square$

Unit clause deletion breaks stuff

x_1 $\quad$ $x_5\,x_6$ $\quad$ $\overline{x_3}\,\overline{x_6}\,x_8$ $\quad$ $\overline{x_4}\,\overline{x_9}\,x_{10}$ $\quad$ x_5

$\overline{x_2}\,\overline{x_5}\,x_7$ $\quad$ $x_3\,\overline{x_4}\,\overline{x_6}$ $\quad$ $x_9\,\overline{x_{10}}$

$\overline{x_1}\,\overline{x_2}\,x_3$ $\quad$ $\overline{x_1}\,\overline{x_5}\,x_6$ $\quad$ $x_5\,\overline{x_8}$ $\quad$ $x_7\,\overline{x_9}$

$\overline{x_1}\,\overline{x_3}\,x_4$ $\quad$ $x_4\,\overline{x_5}\,\overline{x_6}$ $\quad$ $\overline{x_3}\,x_9\,x_{10}$ $\quad$ $\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $\quad$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\,x_2$

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Unit clause deletion breaks stuff

x_1 $x_5\,x_6$ $\overline{x_3}\,\overline{x_6}\,x_8$ $\overline{x_4}\,\overline{x_9}\,x_{10}$ x_5

$\overline{x_2}\,\overline{x_5}\,x_7$ $x_3\,\overline{x_4}\,\overline{x_6}$ $x_9\,\overline{x_{10}}$

$\overline{x_1}\,\overline{x_2}\,x_3$ $\overline{x_1}\,\overline{x_5}\,x_6$ $x_5\,\overline{x_8}$ $x_7\,\overline{x_9}$

$\overline{x_1}\,\overline{x_3}\,x_4$ $x_4\,\overline{x_5}\,\overline{x_6}$ $\overline{x_3}\,x_9\,x_{10}$ $\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\,x_2$

x_1 x_2 x_3 x_4 x_5 x_6 x_7 x_8

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Unit clause deletion breaks stuff

x_1 $x_5\ x_6$ $\overline{x_3}\ \overline{x_6}\ x_8$ $\overline{x_4}\ \overline{x_9}\ x_{10}$ x_5

$\overline{x_2}\ \overline{x_5}\ x_7$ $x_3\ \overline{x_4}\ \overline{x_6}$ $x_9\ \overline{x_{10}}$

$\overline{x_1}\ \overline{x_2}\ x_3$ $\overline{x_1}\ \overline{x_5}\ x_6$ $x_5\ \overline{x_8}$ $x_7\ \overline{x_9}$

$\overline{x_1}\ \overline{x_3}\ x_4$ $x_4\ \overline{x_5}\ \overline{x_6}$ $\overline{x_3}\ x_9\ x_{10}$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

x_1 ~~x_2~~ ~~x_3~~ x_4 x_5 x_6 x_7 x_8

i: x_9

Remove all literals propagated because of x_2

i: □

Unit clause deletion breaks stuff

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$	x_5
	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$	
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$	
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: □

Unit clause deletion breaks stuff

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$	x_5
	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$	
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$	
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Unit clause deletion breaks stuff

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$	x_5
	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$	
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$	
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Unit clause deletion breaks stuff

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$	x_5
	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$	
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$	
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

x_1 ~~x_2 x_3 x_4~~ x_5 x_6 ~~x_7 x_8~~ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: □

Unit clause deletion breaks stuff

x_1 $\quad$ $x_5\,x_6$ $\quad$ $\overline{x_3}\,\overline{x_6}\,x_8$ $\quad$ $\overline{x_4}\,\overline{x_9}\,x_{10}$ $\quad$ x_5

$\overline{x_2}\,\overline{x_5}\,x_7$ $\quad$ $x_3\,\overline{x_4}\,\overline{x_6}$ $\quad$ $x_9\,\overline{x_{10}}$

$\overline{x_1}\,\overline{x_2}\,x_3$ $\quad$ $\overline{x_1}\,\overline{x_5}\,x_6$ $\quad$ $x_5\,\overline{x_8}$ $\quad$ $x_7\,\overline{x_9}$

$\overline{x_1}\,\overline{x_3}\,x_4$ $\quad$ $x_4\,\overline{x_5}\,\overline{x_6}$ $\quad$ $\overline{x_3}\,x_9\,x_{10}$ $\quad$ $\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $\quad$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\,x_2$

$x_1\ x_5\ x_6$ $\quad$ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Unit clause deletion breaks stuff

x_1

$\overline{x_1}\,\overline{x_2}\,x_3$

$\overline{x_1}\,\overline{x_3}\,x_4$

$x_5\,x_6$

$\overline{x_2}\,\overline{x_5}\,x_7$

$\overline{x_1}\,\overline{x_5}\,x_6$

$x_4\,\overline{x_5}\,\overline{x_6}$

$\overline{x_3}\,\overline{x_6}\,x_8$

$x_3\,\overline{x_4}\,\overline{x_6}$

$x_5\,\overline{x_8}$

$\overline{x_3}\,x_9\,x_{10}$

$\overline{x_4}\,\overline{x_9}\,x_{10}$

$x_9\,\overline{x_{10}}$

$x_7\,\overline{x_9}$

$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\,x_2$

$x_1\ x_5\ x_6$

$x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Check clauses with $\overline{x}$ for each removed x

Unit clause deletion breaks stuff

x_1 $x_5\ x_6$ $\overline{x_3}\ \overline{x_6}\ x_8$ $\overline{x_4}\ \overline{x_9}\ x_{10}$ x_5

$\overline{x_2}\ \overline{x_5}\ x_7$ $x_3\ \overline{x_4}\ \overline{x_6}$ $x_9\ \overline{x_{10}}$

$\overline{x_1}\ \overline{x_2}\ x_3$ $\overline{x_1}\ \overline{x_5}\ x_6$ $x_5\ \overline{x_8}$ $x_7\ \overline{x_9}$

$\overline{x_1}\ \overline{x_3}\ x_4$ $x_4\ \overline{x_5}\ \overline{x_6}$ $\overline{x_3}\ x_9\ x_{10}$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_5\ x_6$ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Check clauses with $\overline{x}$ for each removed x

Unit clause deletion breaks stuff

x_1	$x_5\ x_6$	$\overline{x_3}\ \overline{x_6}\ x_8$	$\overline{x_4}\ \overline{x_9}\ x_{10}$	x_5
	$\overline{x_2}\ \overline{x_5}\ x_7$	$x_3\ \overline{x_4}\ \overline{x_6}$	$x_9\ \overline{x_{10}}$	
$\overline{x_1}\ \overline{x_2}\ x_3$	$\overline{x_1}\ \overline{x_5}\ x_6$	$x_5\ \overline{x_8}$	$x_7\ \overline{x_9}$	
$\overline{x_1}\ \overline{x_3}\ x_4$	$x_4\ \overline{x_5}\ \overline{x_6}$	$\overline{x_3}\ x_9\ x_{10}$	$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_5\ x_6\ x_4$ $\quad$ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Check clauses with $\overline{x}$ for each removed x

Unit clause deletion breaks stuff

x_1 $x_5\ x_6$ $\overline{x_3}\ \overline{x_6}\ x_8$ $\overline{x_4}\ \overline{x_9}\ x_{10}$ x_5

$\overline{x_2}\ \overline{x_5}\ x_7$ $x_3\ \overline{x_4}\ \overline{x_6}$ $x_9\ \overline{x_{10}}$

$\overline{x_1}\ \overline{x_2}\ x_3$ $\overline{x_1}\ \overline{x_5}\ x_6$ $x_5\ \overline{x_8}$ $x_7\ \overline{x_9}$

$\overline{x_1}\ \overline{x_3}\ x_4$ $x_4\ \overline{x_5}\ \overline{x_6}$ $\overline{x_3}\ x_9\ x_{10}$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_5\ x_6\ x_4$ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: □

Check clauses with $\overline{x}$ for each removed x

Propagate again

Unit clause deletion breaks stuff

x_1 $x_5\ x_6$ $\overline{x_3}\ \overline{x_6}\ x_8$ $\overline{x_4}\ \overline{x_9}\ x_{10}$ x_5

$\overline{x_2}\ \overline{x_5}\ x_7$ $x_3\ \overline{x_4}\ \overline{x_6}$ $x_9\ \overline{x_{10}}$

$\overline{x_1}\ \overline{x_2}\ x_3$ $\overline{x_1}\ \overline{x_5}\ x_6$ $x_5\ \overline{x_8}$ $x_7\ \overline{x_9}$

$\overline{x_1}\ \overline{x_3}\ x_4$ $x_4\ \overline{x_5}\ \overline{x_6}$ $\overline{x_3}\ x_9\ x_{10}$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_5\ x_6\ x_4$ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Check clauses with $\overline{x}$ for each removed x

Propagate again

Unit clause deletion breaks stuff

x_1 $x_5\ x_6$ $\overline{x_3}\ \overline{x_6}\ x_8$ $\overline{x_4}\ \overline{x_9}\ x_{10}$ x_5

$\overline{x_2}\ \overline{x_5}\ x_7$ $x_3\ \overline{x_4}\ \overline{x_6}$ $x_9\ \overline{x_{10}}$

$\overline{x_1}\ \overline{x_2}\ x_3$ $\overline{x_1}\ \overline{x_5}\ x_6$ $x_5\ \overline{x_8}$ $x_7\ \overline{x_9}$

$\overline{x_1}\ \overline{x_3}\ x_4$ $x_4\ \overline{x_5}\ \overline{x_6}$ $\overline{x_3}\ x_9\ x_{10}$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_5\ x_6\ x_4\ x_3$ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Check clauses with $\overline{x}$ for each removed x

Propagate again

Unit clause deletion breaks stuff

x_1 $x_5\ x_6$ $\overline{x_3}\ \overline{x_6}\ x_8$ $\overline{x_4}\ \overline{x_9}\ x_{10}$ x_5

$\overline{x_2}\ \overline{x_5}\ x_7$ $x_3\ \overline{x_4}\ \overline{x_6}$ $x_9\ \overline{x_{10}}$

$\overline{x_1}\ \overline{x_2}\ x_3$ $\overline{x_1}\ \overline{x_5}\ x_6$ $x_5\ \overline{x_8}$ $x_7\ \overline{x_9}$

$\overline{x_1}\ \overline{x_3}\ x_4$ $x_4\ \overline{x_5}\ \overline{x_6}$ $\overline{x_3}\ x_9\ x_{10}$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4$ $x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_5\ x_6\ x_4\ x_3$ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

Remove all literals propagated because of x_2

i: $\square$

Check clauses with $\overline{x}$ for each removed x

Propagate again

Unit clause deletion breaks stuff

x_1 $x_5\,x_6$ $\overline{x_3}\,\overline{x_6}\,x_8$ $\overline{x_4}\,\overline{x_9}\,x_{10}$ x_5

$\overline{x_2}\,\overline{x_5}\,x_7$ $x_3\,\overline{x_4}\,\overline{x_6}$ $x_9\,\overline{x_{10}}$

$\overline{x_1}\,\overline{x_2}\,x_3$ $\overline{x_1}\,\overline{x_5}\,x_6$ $x_5\,\overline{x_8}$ $x_7\,\overline{x_9}$

$\overline{x_1}\,\overline{x_3}\,x_4$ $x_4\,\overline{x_5}\,\overline{x_6}$ $\overline{x_3}\,x_9\,x_{10}$ $\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\,x_2$

$x_1\ x_5\ x_6\ x_4\ x_3\ x_8$ $x_2\ x_3\ x_4\ x_7\ x_8$

i: x_9

i: $\square$

Remove all literals propagated because of x_2

Check clauses with $\overline{x}$ for each removed x

Propagate again

Unit clause deletion breaks stuff

x_1	$x_5\, x_6$	$\overline{x_3}\,\overline{x_6}\, x_8$	$\overline{x_4}\,\overline{x_9}\, x_{10}$	x_5
	$\overline{x_2}\,\overline{x_5}\, x_7$	$x_3\,\overline{x_4}\,\overline{x_6}$	$x_9\,\overline{x_{10}}$	
$\overline{x_1}\,\overline{x_2}\, x_3$	$\overline{x_1}\,\overline{x_5}\, x_6$	$x_5\,\overline{x_8}$	$x_7\,\overline{x_9}$	
$\overline{x_1}\,\overline{x_3}\, x_4$	$x_4\,\overline{x_5}\,\overline{x_6}$	$\overline{x_3}\, x_9\, x_{10}$	$\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$	

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\, x_2$

$x_1\ x_5\ x_6\ x_4\ x_3\ x_8$

i: x_9

i: □

Unit clause deletion breaks stuff

x_1 $x_5\,x_6$ $\overline{x_3}\,\overline{x_6}\,x_8$ $\overline{x_4}\,\overline{x_9}\,x_{10}$ x_5

$\overline{x_2}\,\overline{x_5}\,x_7$ $x_3\,\overline{x_4}\,\overline{x_6}$ $x_9\,\overline{x_{10}}$

$\overline{x_1}\,\overline{x_2}\,x_3$ $\overline{x_1}\,\overline{x_5}\,x_6$ $x_5\,\overline{x_8}$ $x_7\,\overline{x_9}$

$\overline{x_1}\,\overline{x_3}\,x_4$ $x_4\,\overline{x_5}\,\overline{x_6}$ $\overline{x_3}\,x_9\,x_{10}$ $\overline{x_7}\,\overline{x_8}\,\overline{x_9}\,\overline{x_{10}}$

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\,x_2$

$x_1\ x_5\ x_6\ x_4\ x_3\ x_8$

i: x_9

How do we reconstruct the trace during backwards checking?

i: □

Unit clause deletion breaks stuff

x_1

$\overline{x_1}\ \overline{x_2}\ x_3$

$\overline{x_1}\ \overline{x_3}\ x_4$

$x_5\ x_6$

$\overline{x_2}\ \overline{x_5}\ x_7$

$\overline{x_1}\ \overline{x_5}\ x_6$

$x_4\ \overline{x_5}\ \overline{x_6}$

$\overline{x_3}\ \overline{x_6}\ x_8$

$x_3\ \overline{x_4}\ \overline{x_6}$

$x_5\ \overline{x_8}$

$\overline{x_3}\ x_9\ x_{10}$

$\overline{x_4}\ \overline{x_9}\ x_{10}$

$x_9\ \overline{x_{10}}$

$x_7\ \overline{x_9}$

$\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$

x_5

$x_1\ x_2\ x_3\ x_4$

i: x_5

$x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8$

d: $\overline{x_1}\ x_2$

$x_1\ x_5\ x_6\ x_4\ x_3\ x_8$

i: x_9

How do we reconstruct the trace during backwards checking?

i: □

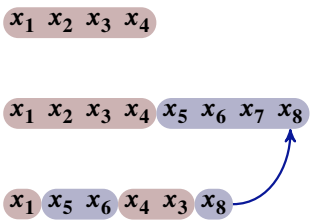
Unit clause deletion breaks stuff

x_1 $\quad$ $x_5\ x_6$ $\quad$ $\overline{x_3}\ \overline{x_6}\ x_8$ $\quad$ $\overline{x_4}\ \overline{x_9}\ x_{10}$ $\quad$ x_5

$\overline{x_2}\ \overline{x_5}\ x_7$ $\quad$ $x_3\ \overline{x_4}\ \overline{x_6}$ $\quad$ $x_9\ \overline{x_{10}}$

$\overline{x_1}\ \overline{x_2}\ x_3$ $\quad$ $\overline{x_1}\ \overline{x_5}\ x_6$ $\quad$ $x_5\ \overline{x_8}$ $\quad$ $x_7\ \overline{x_9}$

$\overline{x_1}\ \overline{x_3}\ x_4$ $\quad$ $x_4\ \overline{x_5}\ \overline{x_6}$ $\quad$ $\overline{x_3}\ x_9\ x_{10}$ $\quad$ $\overline{x_7}\ \overline{x_8}\ \overline{x_9}\ \overline{x_{10}}$



How do we reconstruct the trace during backwards checking?

Just store it in memory

Are we done yet?

Are we done yet?

I’d wish.

Are we done yet?

I'd wish.

Two-watched literal schema makes unit propagation efficient

Are we done yet?

I'd wish.

Two-watched literal schema makes unit propagation efficient

Problem our procedure breaks the invariants that make it work

Are we done yet?

I'd wish.

Two-watched literal schema **makes unit propagation efficient**

Problem **our procedure breaks the invariants that make it work**

Solution (kind of) **restore the invariants clause by clause**

overall, 85% of the time is spent on unit clause deletion

Are we done yet?

I'd wish.

Two-watched literal schema **makes unit propagation efficient**

Problem **our procedure breaks the invariants that make it work**

Solution (kind of) **restore the invariants clause by clause**

overall, 85% of the time is spent on unit clause deletion

Optimizations

- **Efficient causal cone detection**

Are we done yet?

I'd wish.

Two-watched literal schema makes unit propagation efficient

Problem our procedure breaks the invariants that make it work

Solution (kind of) restore the invariants clause by clause

overall, 85% of the time is spent on unit clause deletion

Optimizations

- Efficient causal cone detection
- Compress traces before storing them to memory

Are we done yet?

I'd wish.

Two-watched literal schema makes unit propagation efficient

Problem our procedure breaks the invariants that make it work

Solution (kind of) restore the invariants clause by clause

overall, 85% of the time is spent on unit clause deletion

Optimizations

- Efficient causal cone detection
- Compress traces before storing them to memory
- Restore invariants only where really needed by exploiting other invariants

Are we done yet?

I'd wish.

Two-watched literal schema **makes unit propagation efficient**

Problem **our procedure breaks the invariants that make it work**

Solution (kind of) **restore the invariants clause by clause**

overall, 85% of the time is spent on unit clause deletion

Optimizations

- **Efficient causal cone detection**
- **Compress traces before storing them to memory**
- **Restore invariants only where really needed by exploiting other invariants**

Result **negligible overhead of unit clause deletion!**

Conclusion

Conclusion

Contributions

- Can we check sDRAT as efficiently as oDRAT?
- How often do discrepancies occur in practice?

Conclusion

Contributions

- Can we check sDRAT as efficiently as oDRAT? Very likely
- How often do discrepancies occur in practice?

Conclusion

Contributions

- Can we check sDRAT as efficiently as oDRAT? Very likely
- How often do discrepancies occur in practice? Quite a lot

Conclusion

Contributions

- Can we check sDRAT as efficiently as oDRAT? Very likely
- How often do discrepancies occur in practice? Quite a lot

There seems to be no proof checking-based reason to prefer oDRAT over sDRAT.

Conclusion

Contributions

- Can we check sDRAT as efficiently as oDRAT? Very likely
- How often do discrepancies occur in practice? Quite a lot

There seems to be no proof checking-based reason to prefer oDRAT over sDRAT.

Proof generation methods are inserting unnecessary deletions.

Conclusion

Contributions

- Can we check sDRAT as efficiently as oDRAT? Very likely
- How often do discrepancies occur in practice? Quite a lot

There seems to be no proof checking-based reason to prefer oDRAT over sDRAT.

Proof generation methods are inserting unnecessary deletions.

We conjecture that proofs can be generated according to the specification, and that proofs can be checked under the specification with similar performance to that of state-of-the-art DRAT checkers.