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Taking Advantage of Properties and Dataflow in Difference Verification

Marie-Christine Jakobs
joint work with Tim Pollandt

The Modification Challenge

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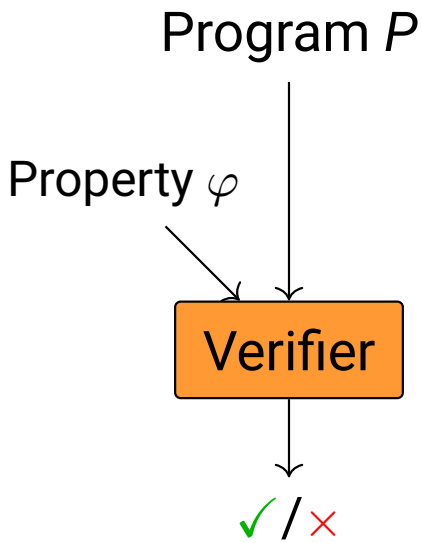

The Modification Challenge

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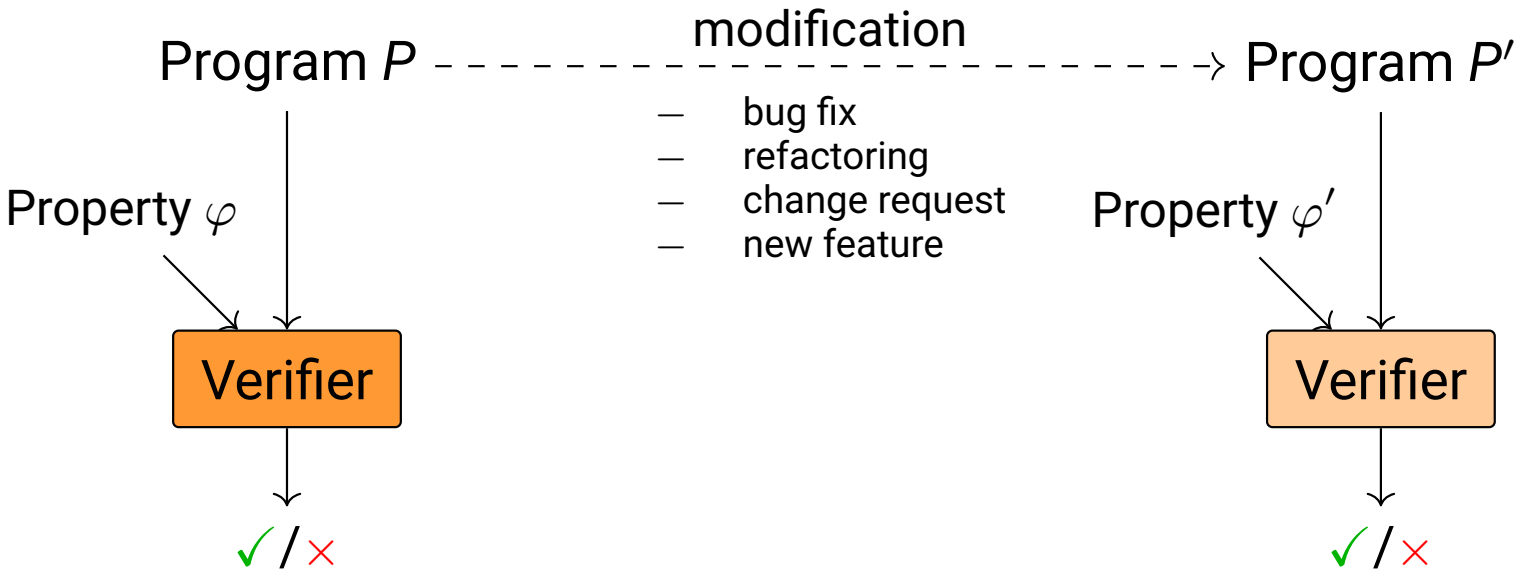

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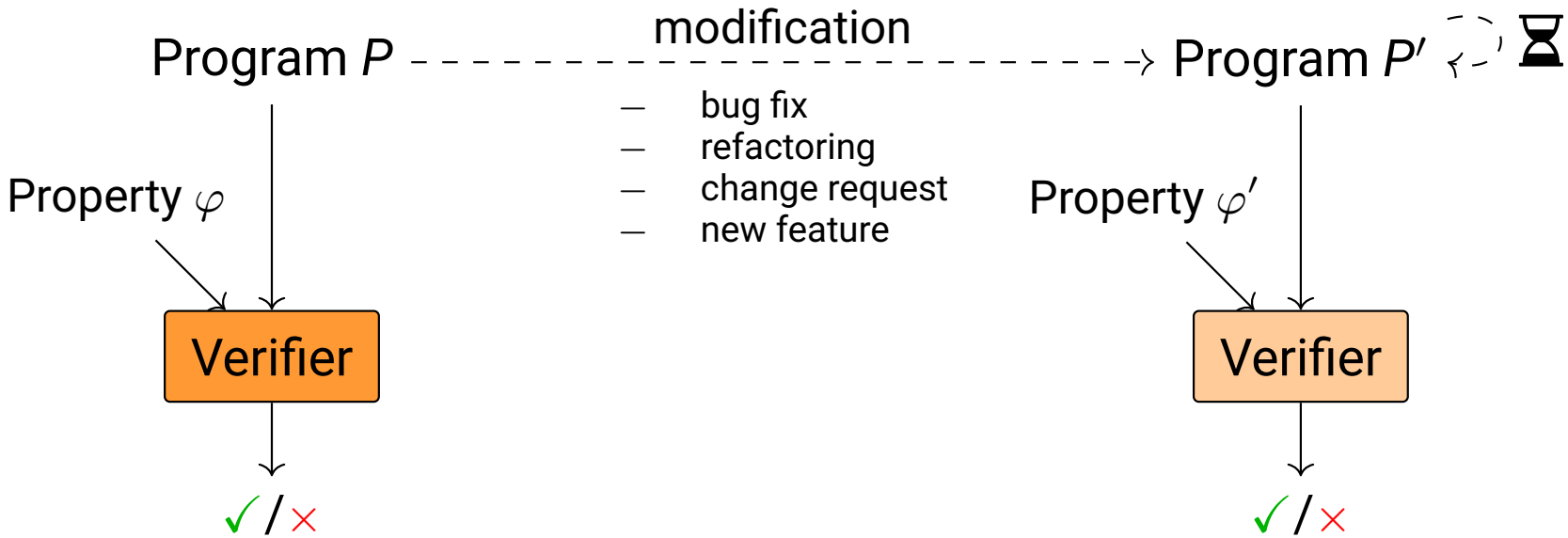

Challenge:

- Programs change frequently
- Reverification necessary after each change
- Reverification must keep up with changes

$\Longrightarrow$ Verification of every modified program **infeasible!**

Suggested Solution: Only Look for New Bugs

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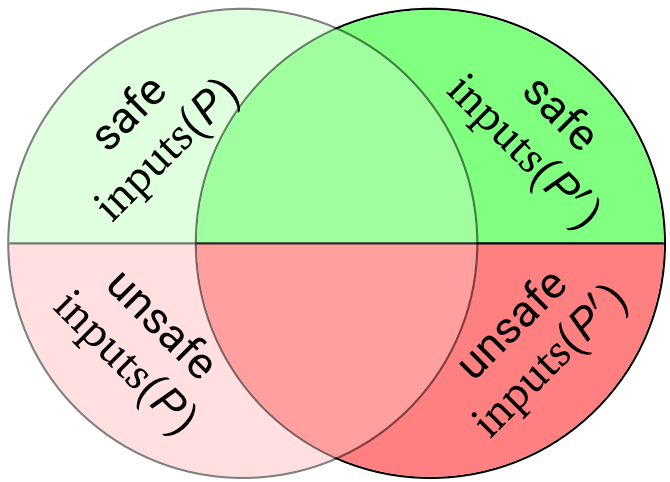

Suggested Solution: Only Look for New Bugs

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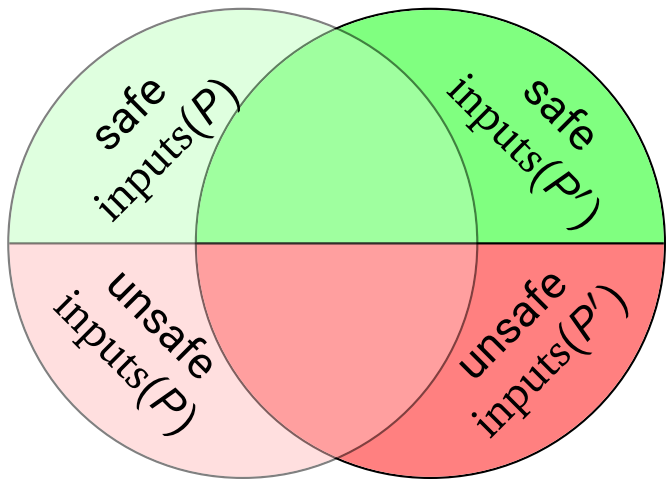
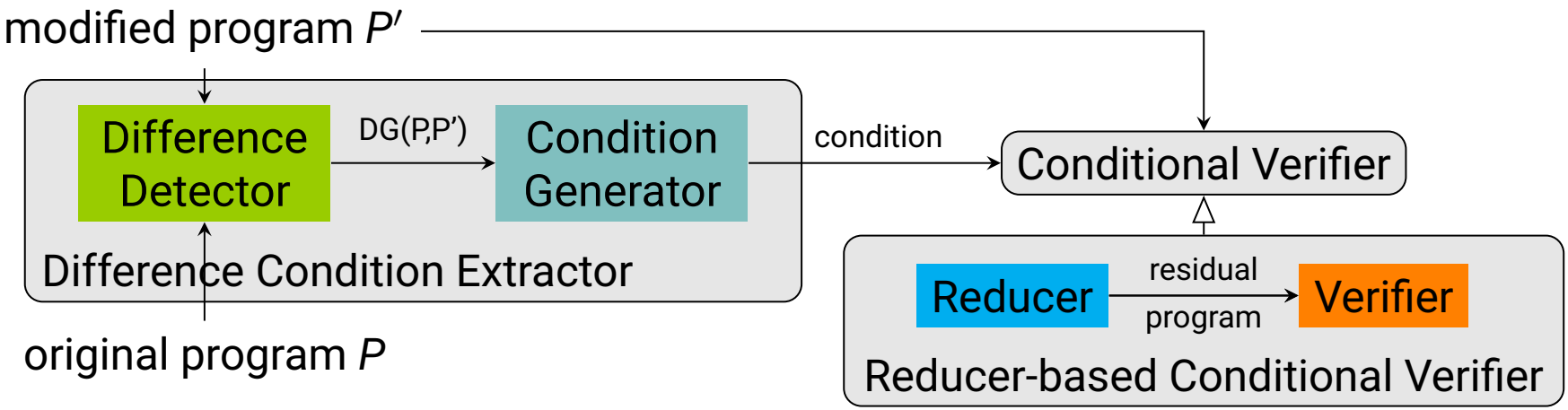


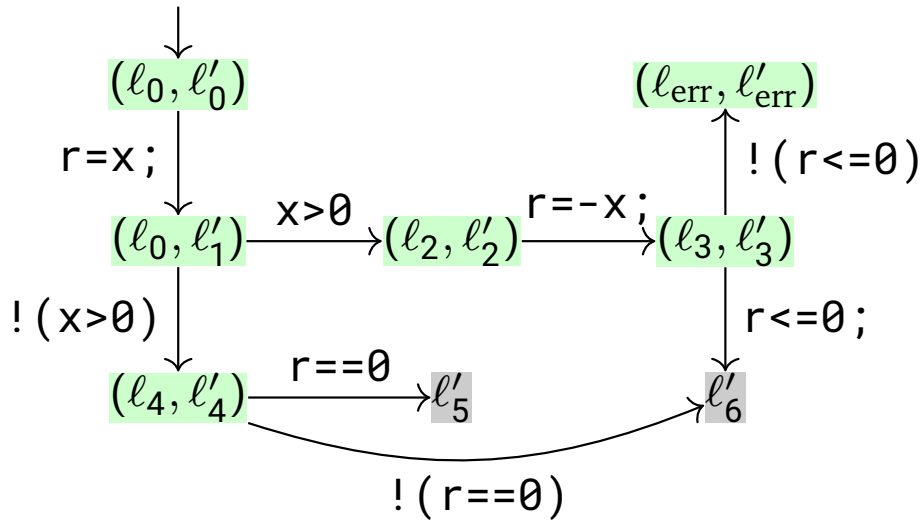
Approach: Overapproximate and then verify (syntactical) paths with new bugs

Difference Verifier



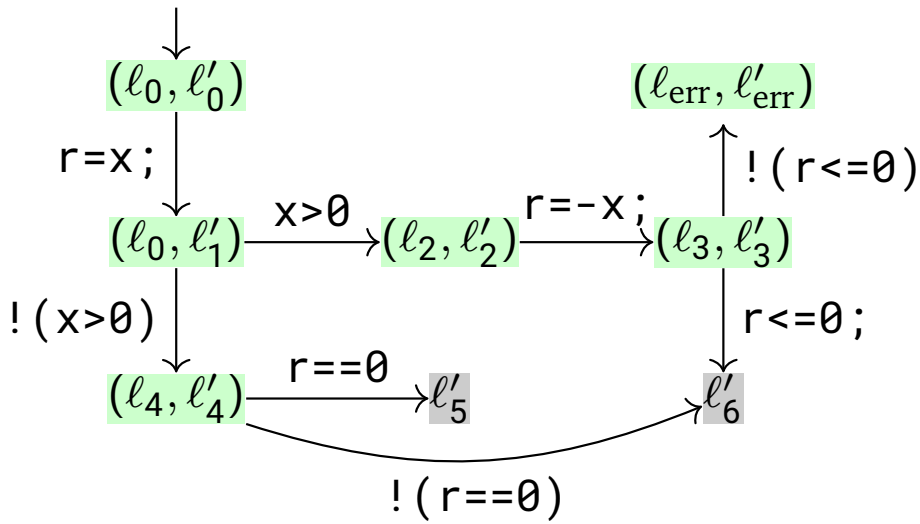
- Difference condition extractor overapproximates relevant paths
  - Difference detector determine relevant paths
  - Condition generator encodes paths into conditions
- Conditional verifier restricts analysis to identified paths

Difference Graphs Characterizing New Bugs



- Paths relate to execution paths of the modified program
- Any path that matches to a prefix of a new bug must be extendable s.t.
  1. it stil matches to a prefix of the new bug
  2. ends in a relevant (Δ-)node (grey nodes)

Condition Generation from Difference Graph



Input: difference graph (N, E, n_0, Δ)
Output: extracted condition

1: $Q = \{n_0\} \cup \Delta$; $\texttt{waitlist} = \{n_0\} \cup \Delta$;
2: **while** ($\texttt{waitlist} \neq \emptyset$) **do**
3: pop n_s from waitlist
4: **for** each $(n_p, (\ell, op, \ell'), n_s) \in E$ with $n_p \notin Q$ **do**
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8: **return** $(Q \cup F, E \cap (Q \times G' \times (Q \cup F)), n_0, F)$;

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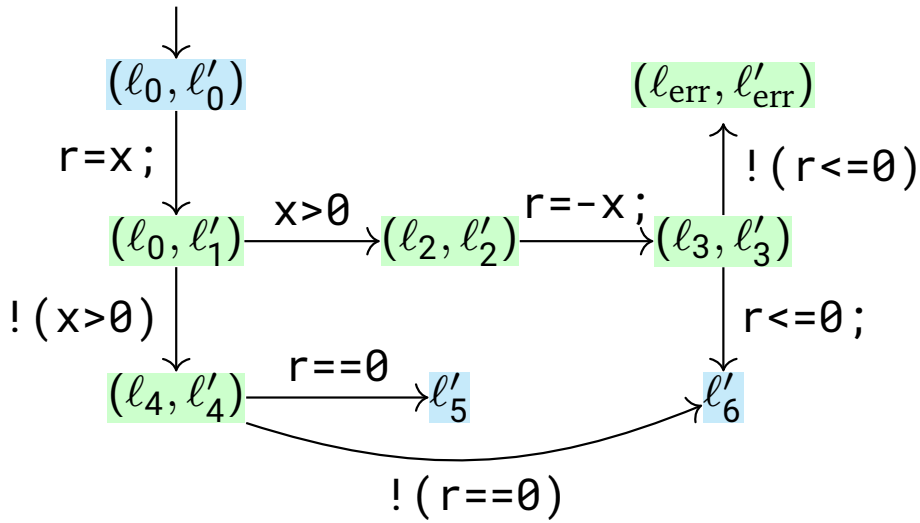

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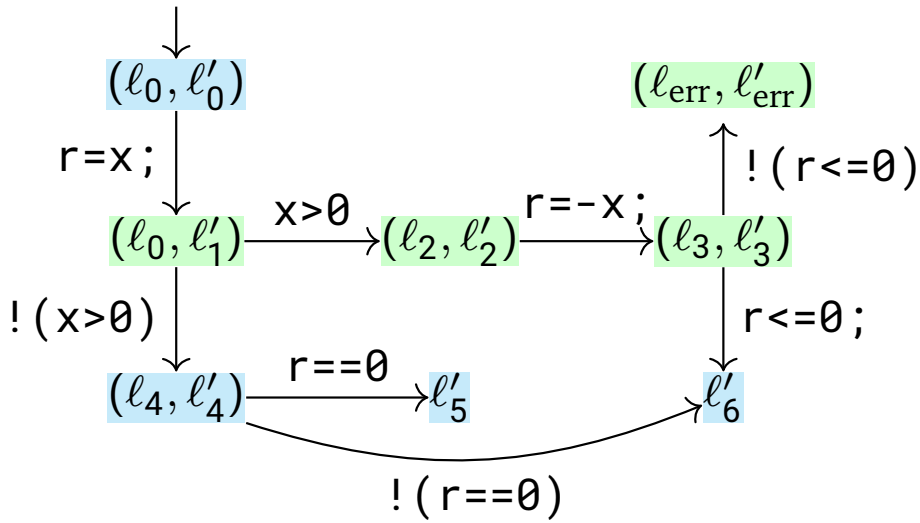

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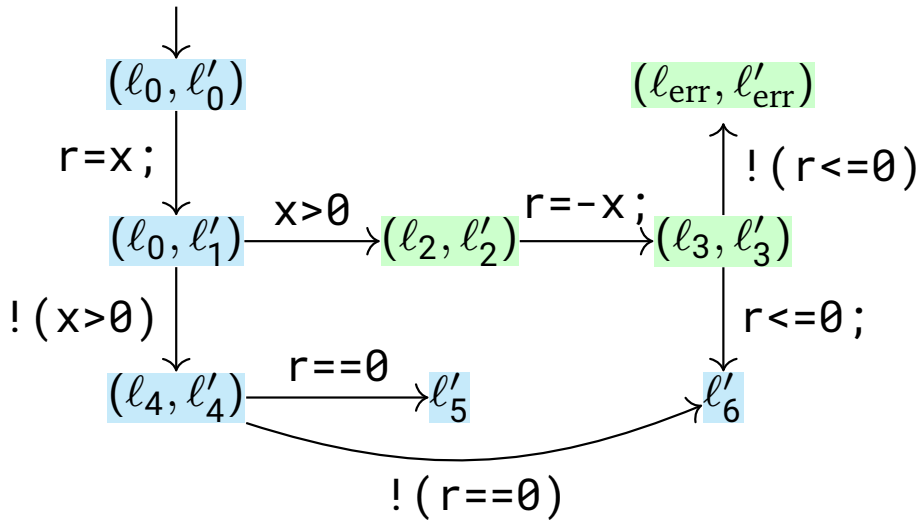

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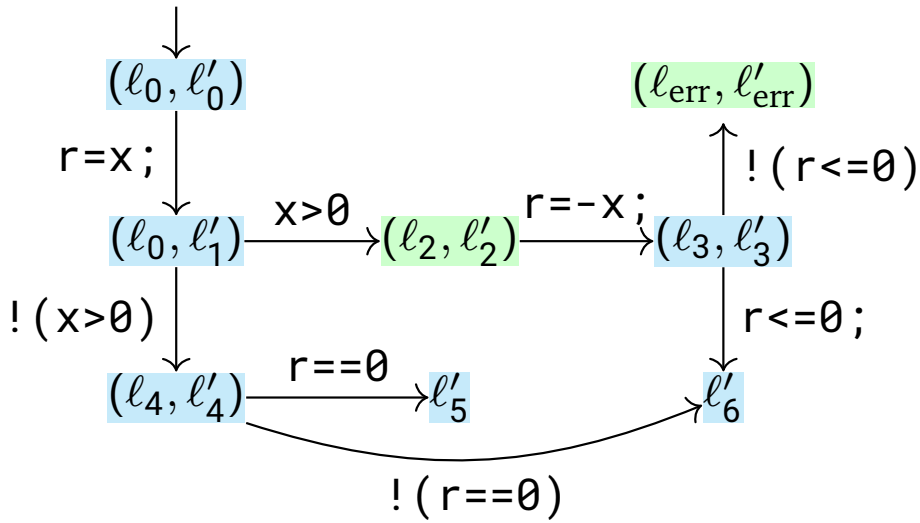

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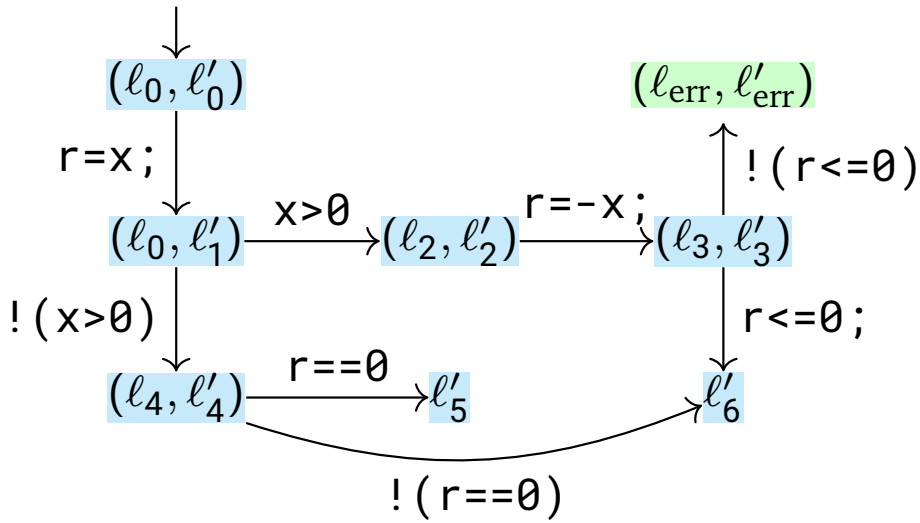

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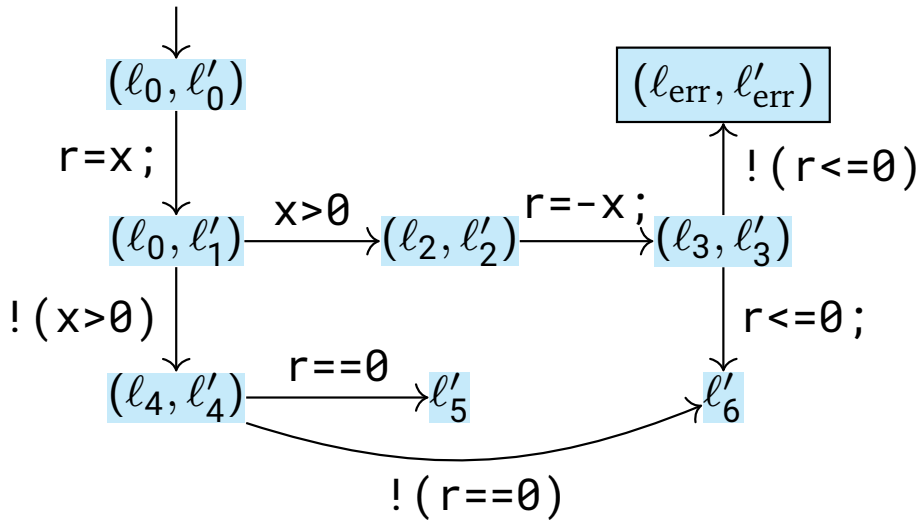

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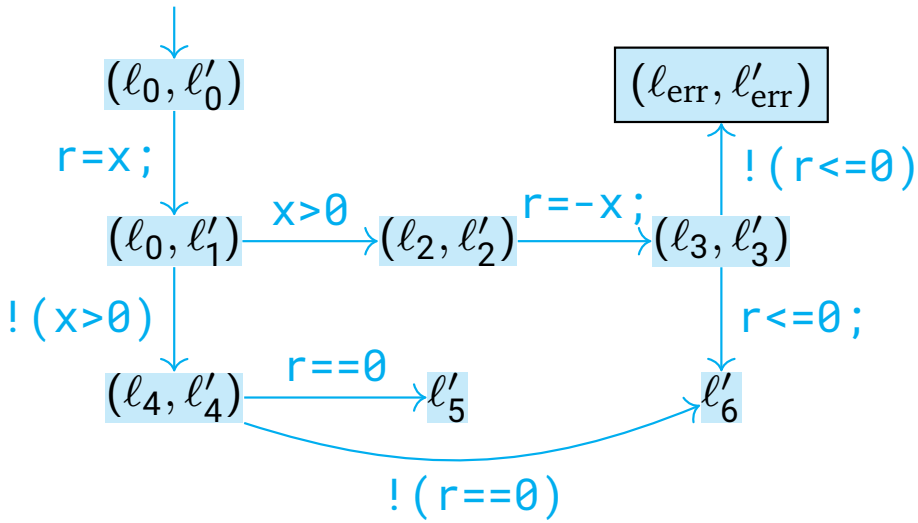

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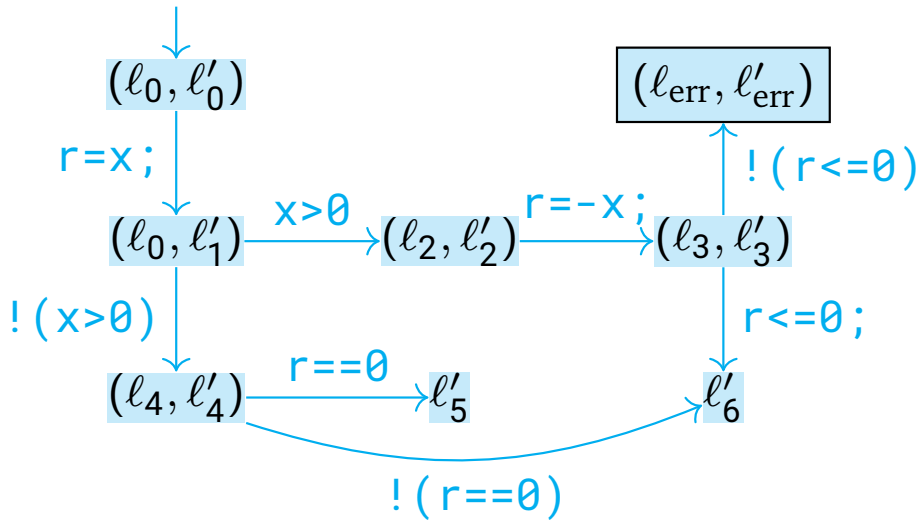

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Theorem

Let $DG(P, P')$ be a difference graph for programs P and P'. The condition generator outputs a condition that does not cover paths that cause new bugs.

DIFFCOND: Computing Difference Graphs Based on Syntactic Changes

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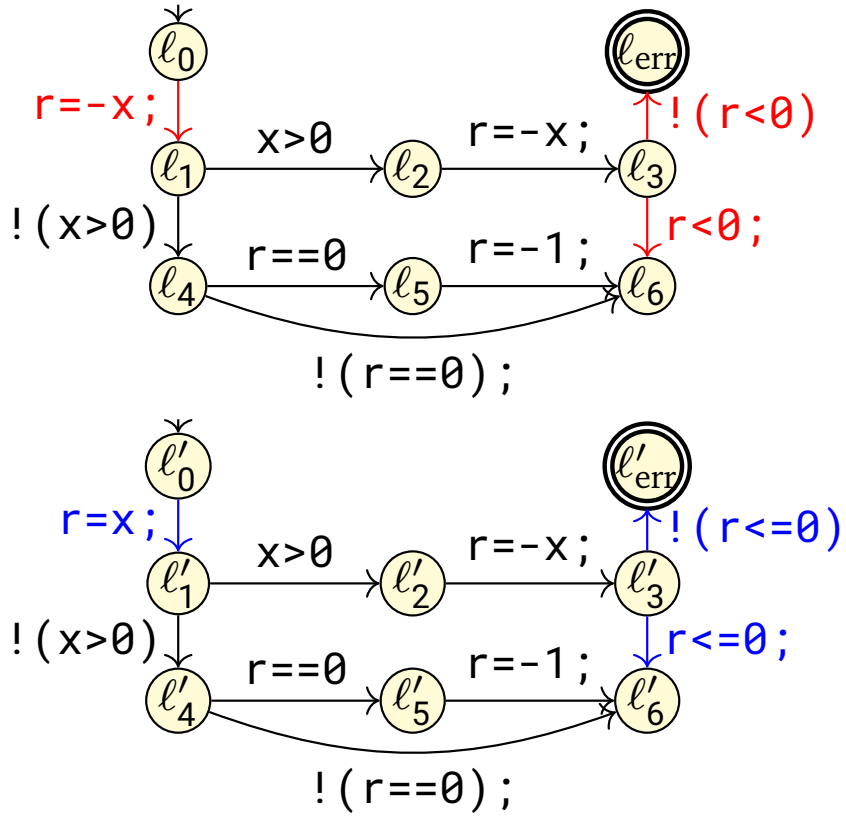

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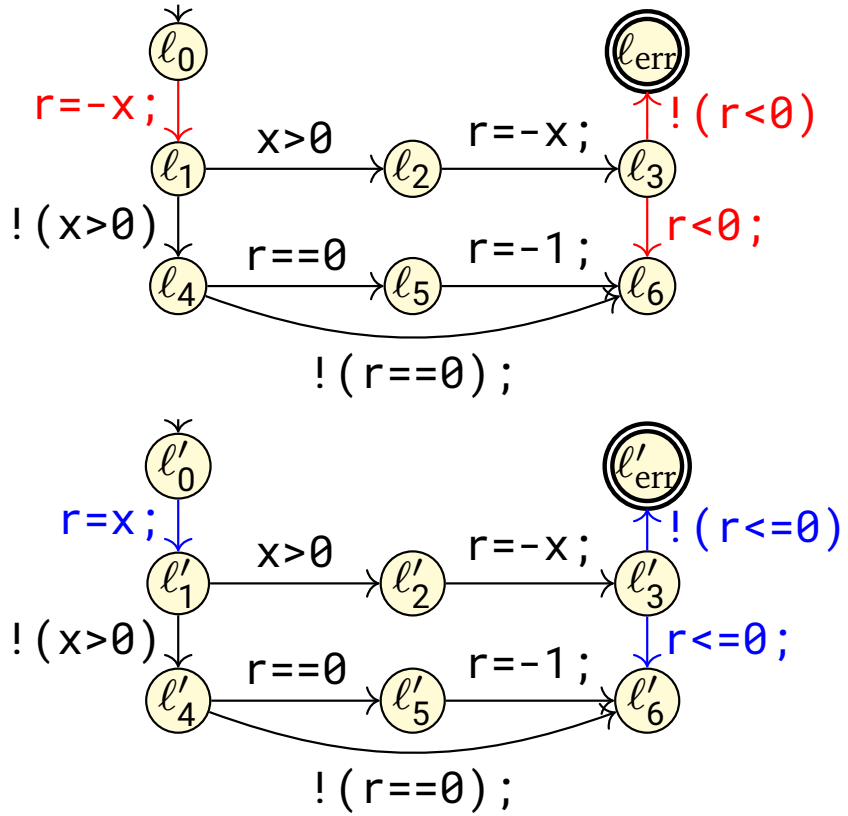

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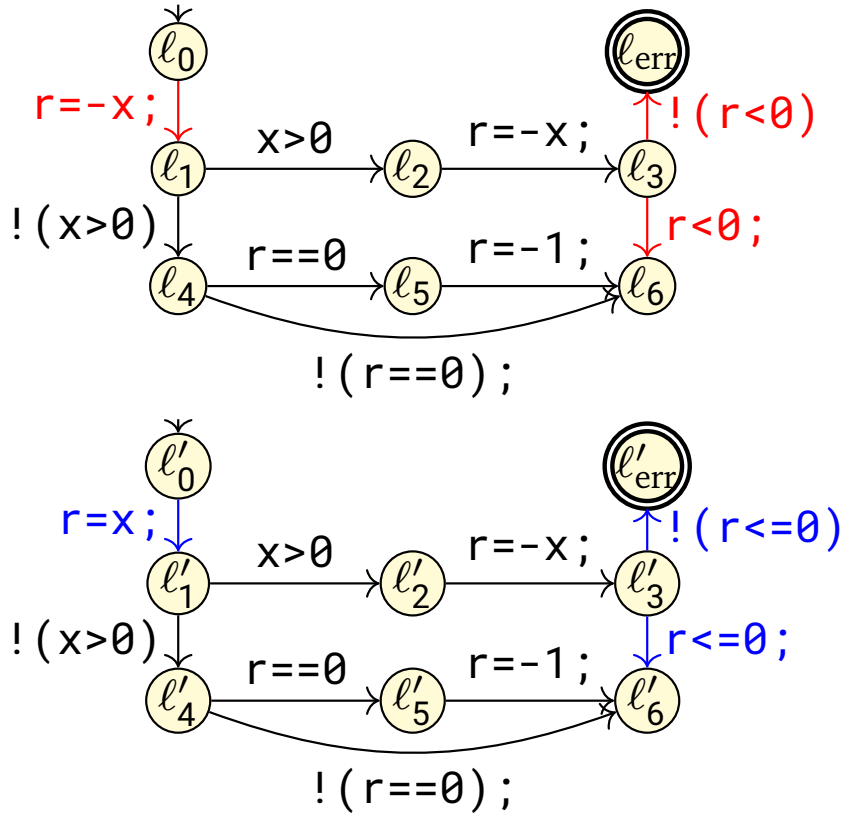

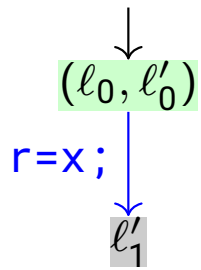

DIFFDP: Utilizing Property and Dataflow to Compute a More Precise Difference Graphs

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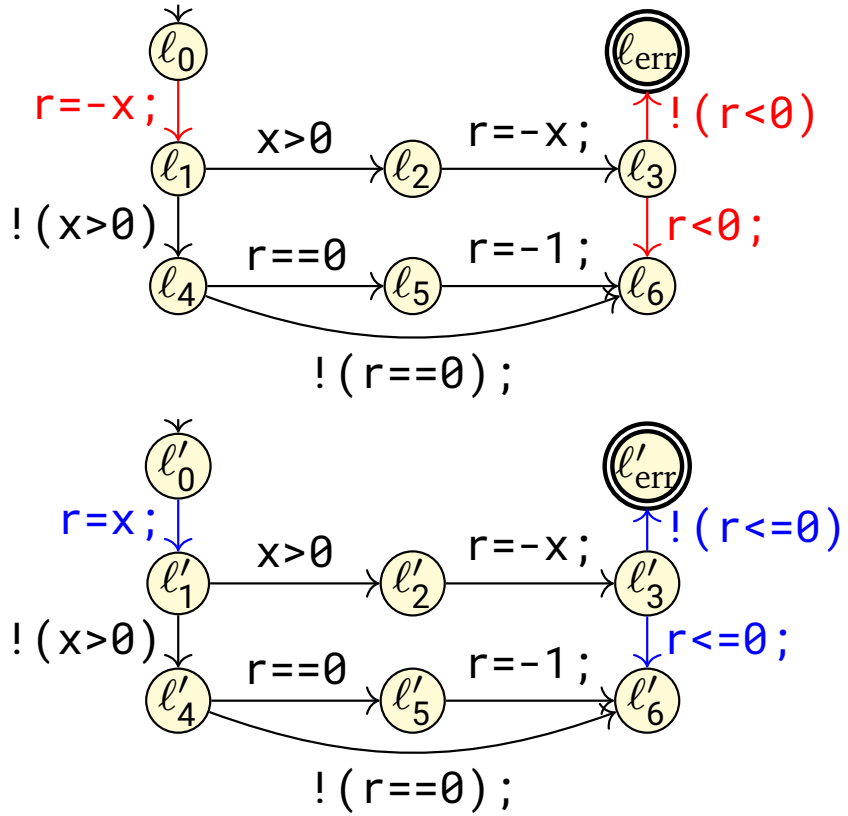

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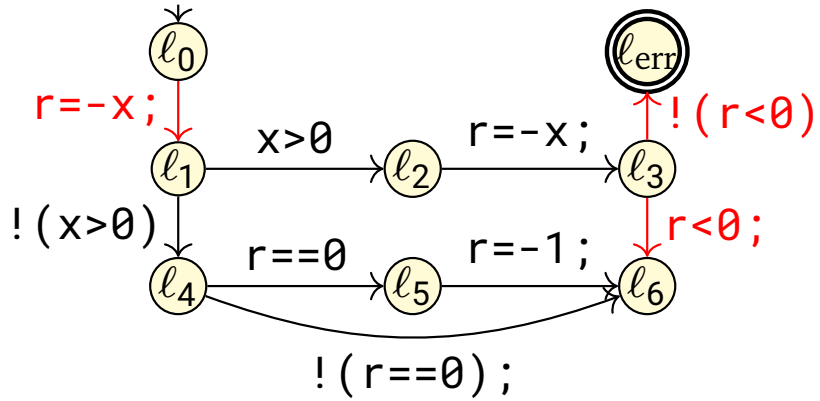

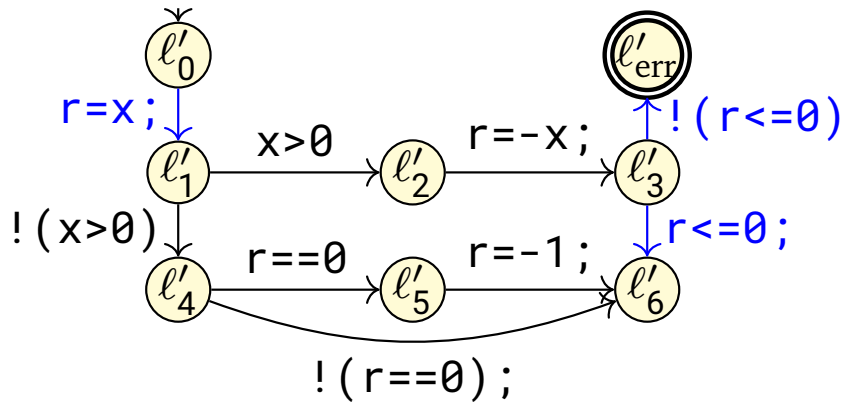

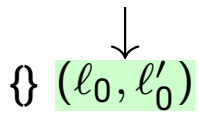

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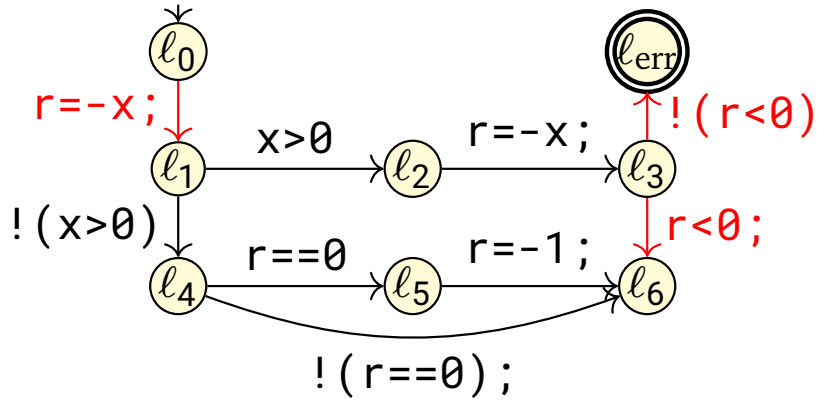

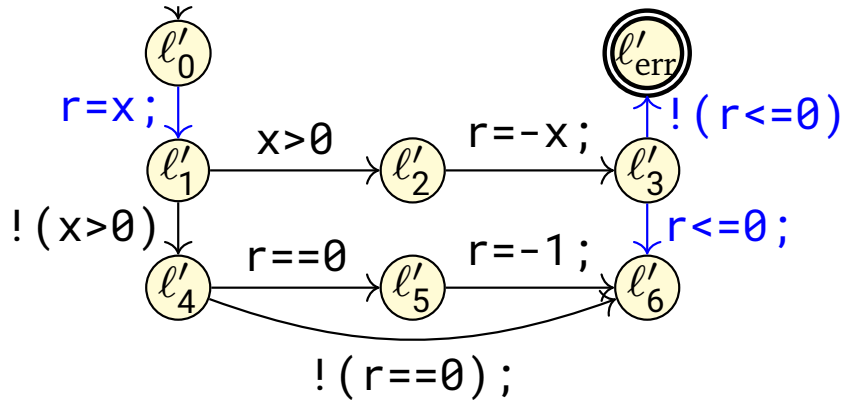

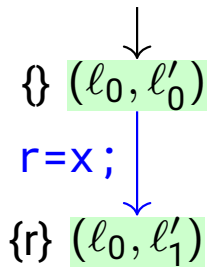

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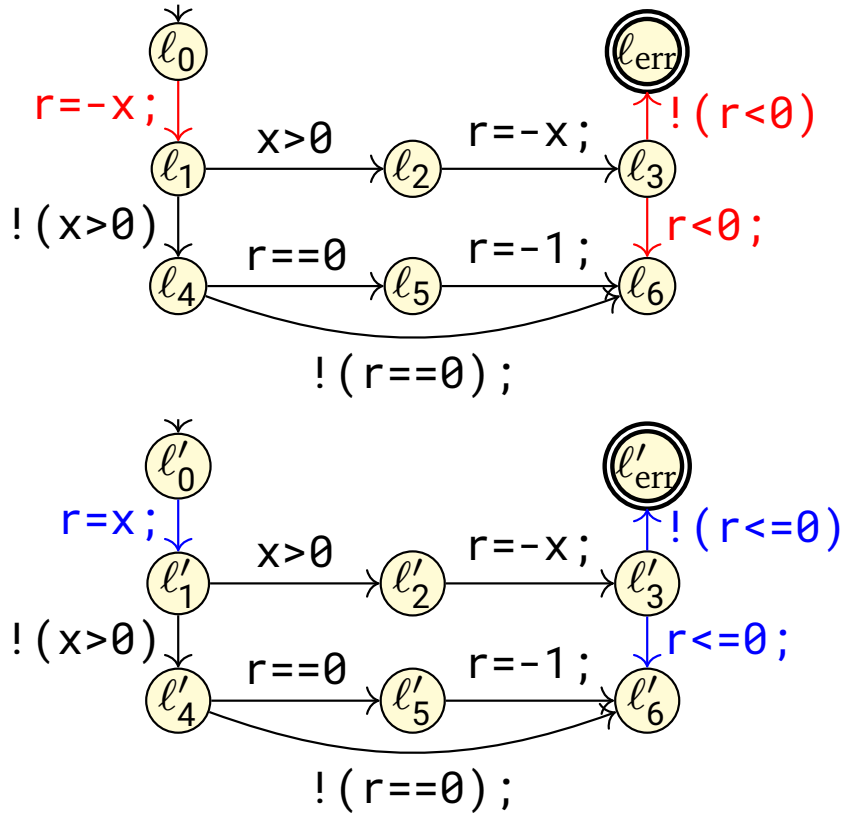

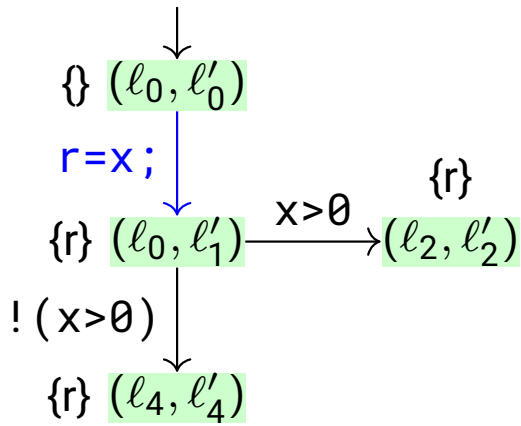

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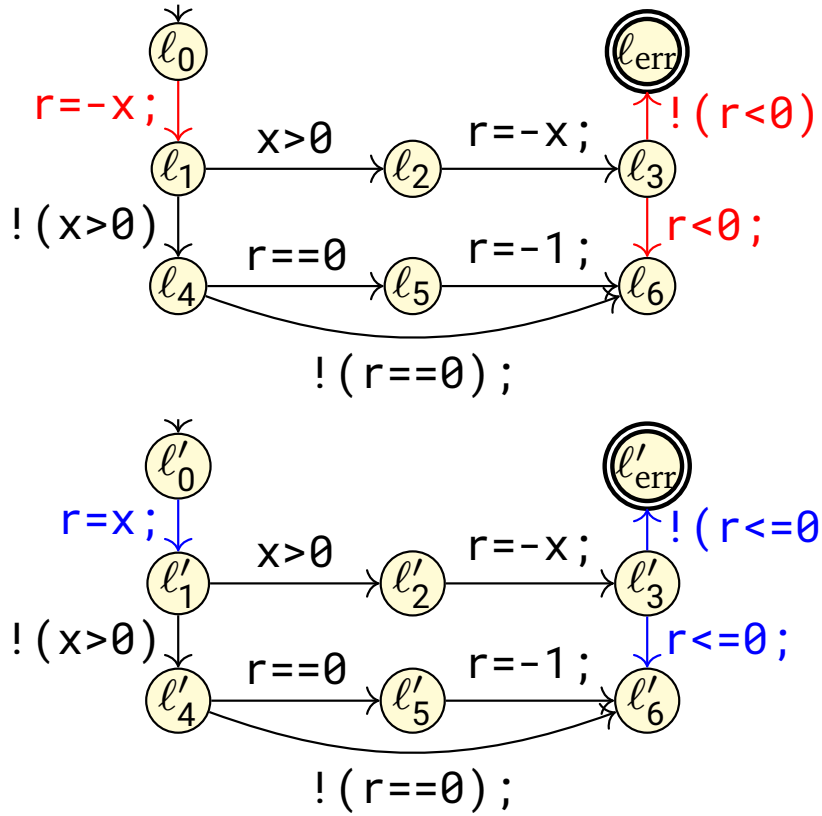

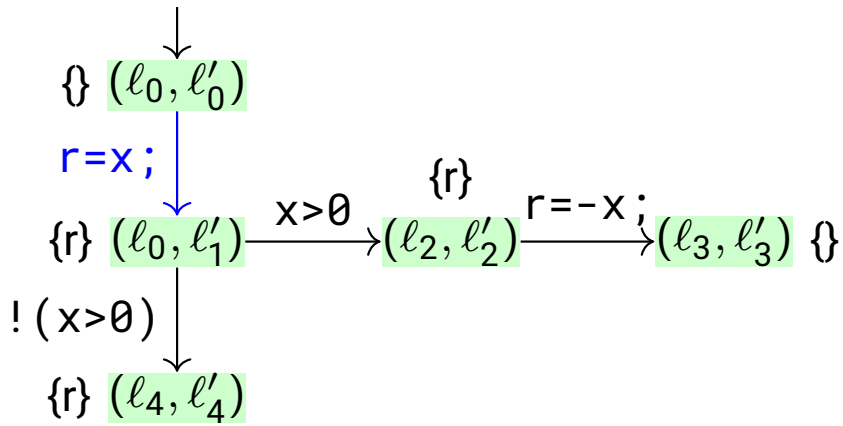

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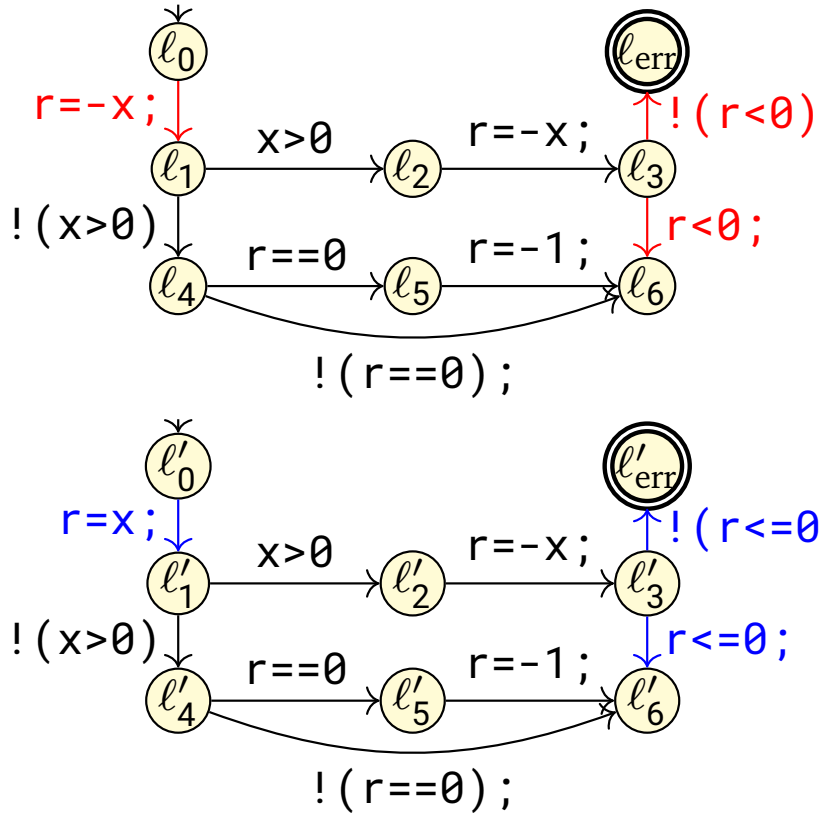

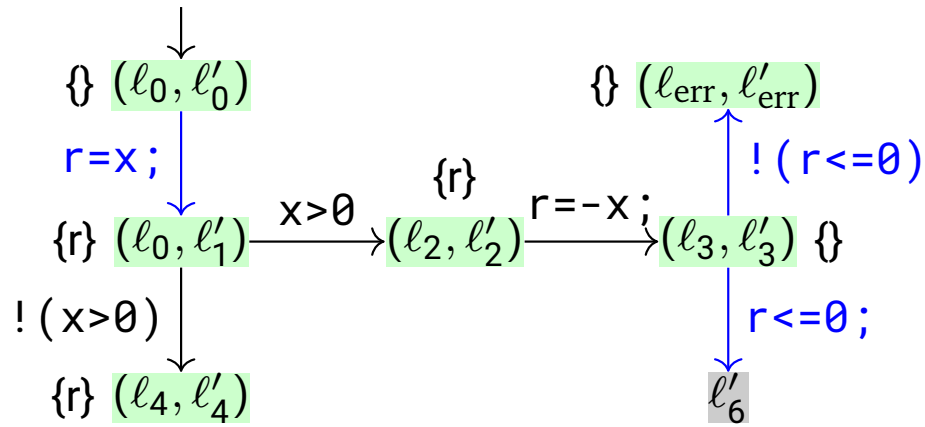

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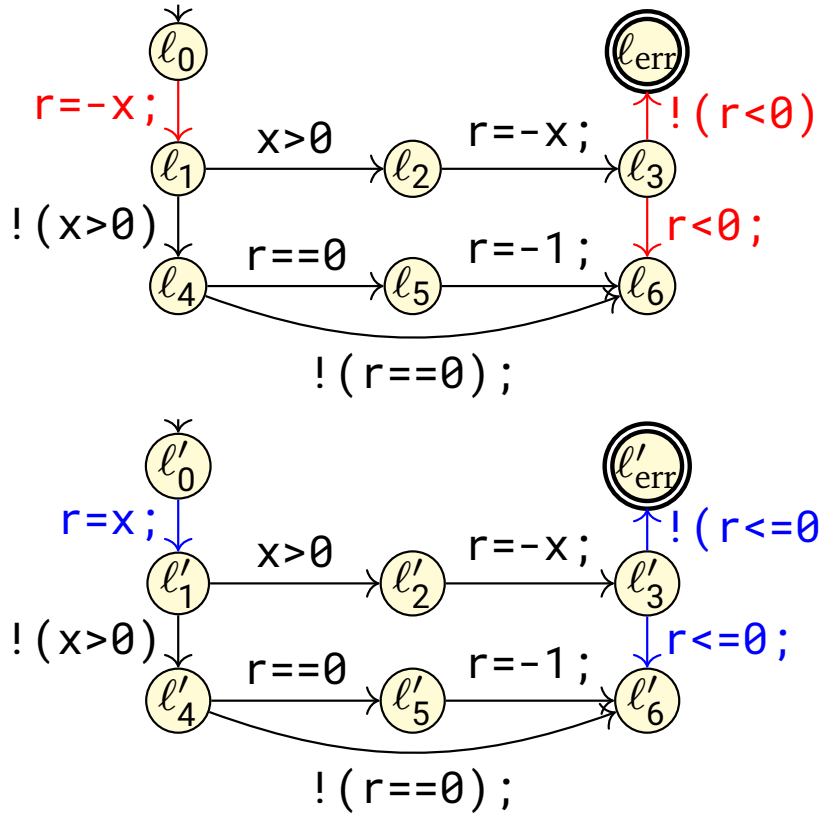

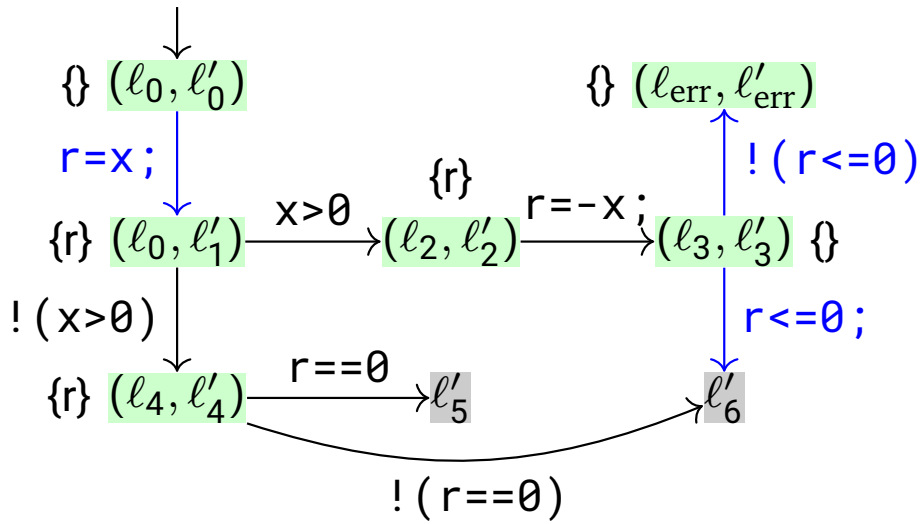

Soundness Result for DIFFDP

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Theorem

DIFFDP *returns a difference graph.*

Evaluation

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Verifiers: ESBMC, CPAchecker, Predicate

Difference Detectors: All, DIFFCOND, DIFFDP

Tasks:
- combination tasks eca05+token, gcd+newton, pals+eca12, sfifo+token, square+softflt
- regression verification tasks

Environment: Intel Xeon E3-1230 v5 CPU, 33 GB, Ubuntu 20.04
- 4 processing units, 15 GB of memory
- 15 min of CPU time

More Effective Than Full Verification? (All vs. DIFFDP)

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	eca05+token (2 340+1 300)			gcd+newton (1 352+572)			pals+eca12 (1 700+1 050)			sfifo+token (1 206+663)			square+softflt (165+75)			regression (3 936+0)		
	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$
PREDICATE	912	1040	0	0	520	0	0	50	0	558	**507**	0	22	51	0	2595	0	0
PREDICATE$^{\Delta^{\text{nat}}_{\text{DP}}}$	**1400**	**985**	0	**156**	520	0	**125**	**75**	0	**594**	488	0	**115**	**75**	0	**2663**	0	0
PREDICATE	912	**1040**	0	0	520	0	0	50	0	558	**507**	0	22	51	0	2595	0	0
PREDICATE$^{\Delta^{\text{red}}_{\text{DP}}}$	**1390**	955	0	**156**	**572**	0	**125**	50	0	**639**	456	0	**135**	**60**	0	**2685**	0	0
CPACHECKER	633	**1296**	0	0	494	0	0	100	0	434	510	0	0	**75**	0	**3931**	0	0
CPACHECKER$^{\Delta^{\text{red}}_{\text{DP}}}$	**1119**	1252	0	**156**	**520**	0	**671**	**500**	0	**480**	**638**	0	**117**	60	0	3618	0	0
ESBMC	0	**1125**	0	570	572	0	**198**	**530**	**0**	0	**663**	0	165	75	0	0	0	0
ESBMC$^{\Delta^{\text{red}}_{\text{DP}}}$	0	900	0	**880**	572	0	0	70	10	**101**	618	0	156	75	0	0	0	0

Difference verification with DIFFDP condition extractor often more effective

More Efficient Than Full Verification? (All vs. DIFFDP)

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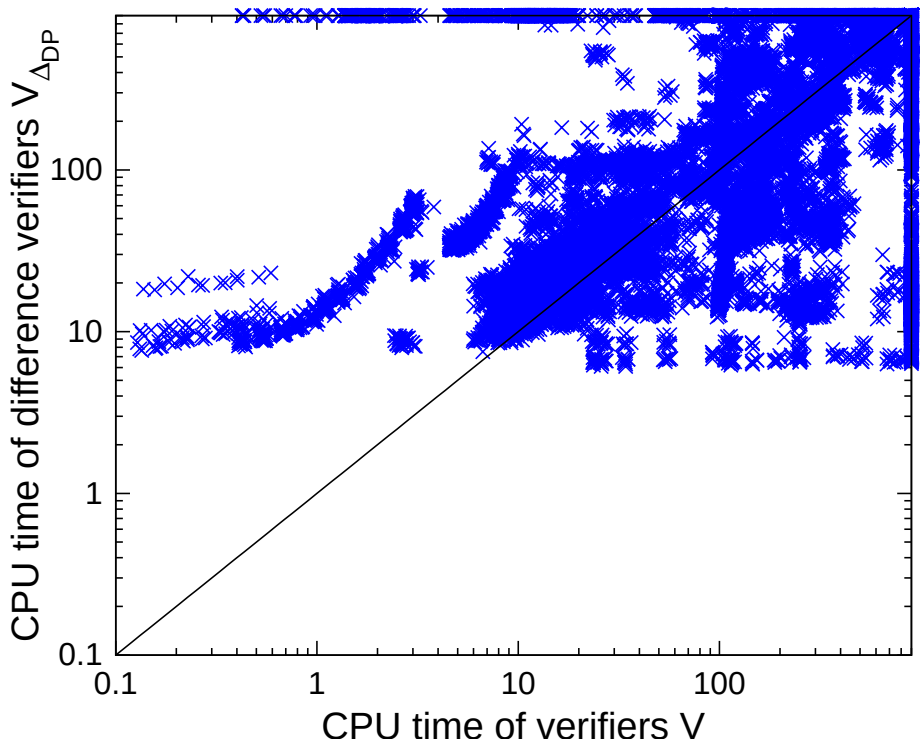

- Conditional verifier faster
- Detector time sometimes too costly to be beneficial

Difference Verification With DIFFDP More Effective Then With DIFFCOND?

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	eca05+token (2 340+1 300)			gcd+newton (1 352+572)			pals+eca12 (1 700+1 050)			sfifo+token (1 206+663)			square+softflt (165+75)			regression (3 936+0)		
	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$	✓	✗	ϟ$_3$
PREDICATE$^{\Delta^{\text{nat}}_{\text{syn}}}$	1395	**987**	0	48	520	0	10	52	0	589	481	0	61	75	0	2599	0	0
PREDICATE$^{\Delta^{\text{nat}}_{\text{DP}}}$	**1400**	985	0	**156**	520	0	**125**	**75**	0	**594**	**488**	0	**115**	75	0	**2663**	0	0
PREDICATE$^{\Delta^{\text{red}}_{\text{syn}}}$	**1394**	**975**	0	48	474	0	10	**95**	0	**642**	**468**	0	81	45	0	2639	0	0
PREDICATE$^{\Delta^{\text{red}}_{\text{DP}}}$	1390	955	0	**156**	**572**	0	**125**	50	0	639	456	0	**135**	**60**	0	**2685**	0	0
CPACHECKER$^{\Delta^{\text{red}}_{\text{syn}}}$	1000	**1282**	0	48	469	0	41	140	0	480	**663**	0	61	45	0	**3906**	0	0
CPACHECKER$^{\Delta^{\text{red}}_{\text{DP}}}$	**1119**	1252	0	**156**	**520**	0	**671**	**500**	0	480	638	0	**117**	**60**	0	3618	0	0
ESBMC$^{\Delta^{\text{red}}_{\text{syn}}}$	0	0	0	333	572	0	0	0	**0**	0	78	0	105	75	0	0	0	0
ESBMC$^{\Delta^{\text{red}}_{\text{DP}}}$	0	**900**	0	**880**	572	0	0	**70**	10	101	618	0	**156**	75	0	0	0	0

Difference verification with DIFFDP often more effective

Difference Verification With DIFFDP More Efficient Then With DIFFCOND?

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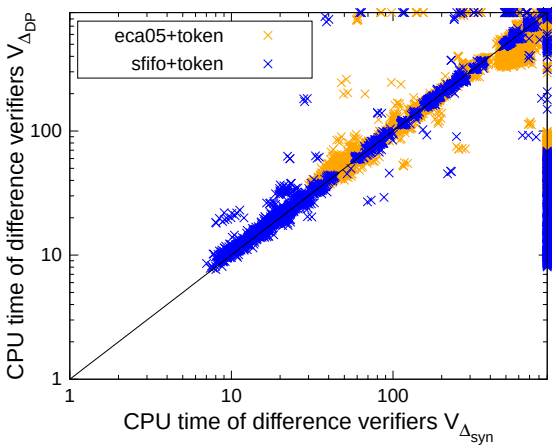

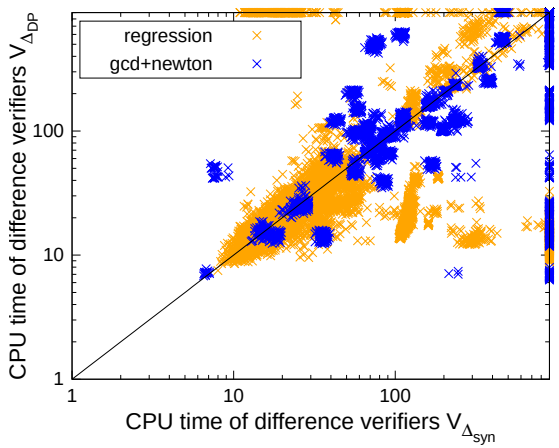

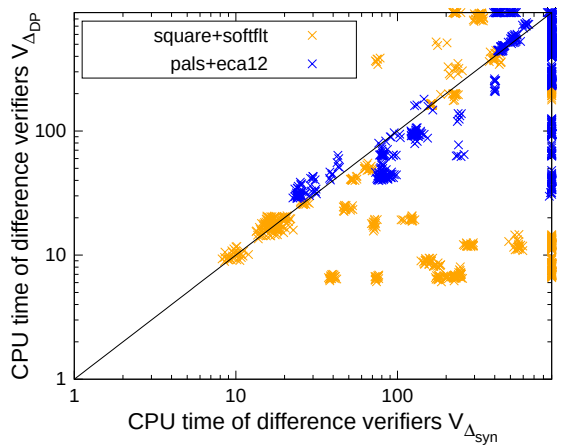

Difference verification with DIFFDP more efficient for several tasks

Conclusion

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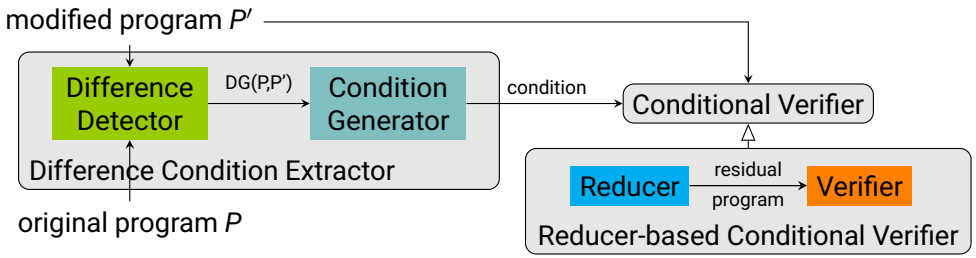

- More sophisticated, sound difference detector
- More effective and efficient than full verification on several tasks
- Better than existing syntax based difference detector on several tasks