Software Verification with PDR:

An Implementation of the State of the Art

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Contributions

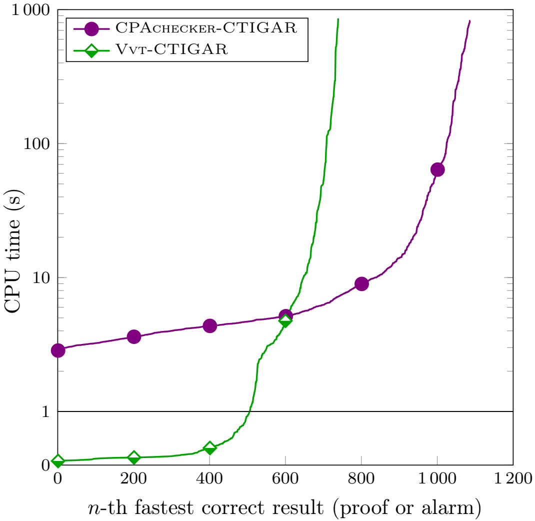
- Implement one adaptation of PDR to software verification
- Design and implement the invariant generator KIPDR (helping k-induction by providing better invariants)
- Large experimental study to compare several approaches (VTT, CPAchecker, k-induction, SeaHorn, VVT-Portfolio)
- Set of small examples that need 'difficult' invariants

Background

- Property-Driven Reachability (PDR) [7, 8, 9, 14]
  received a lot of attention and
  successful for hardware designs
- CTIGAR and Vienna Verification Toolkit (VVT) [6, 10]
  the approach that we followed
- Integrate with k-induction [4, 5, 13]
  our solution for a fully integrated approach
- Compare with VVT and SeaHorn [10, 12, 11]
  establish a new state-of-the-art reference implementation

Eval: Suitability of CPAchecker for PDR.

- Two implementations of CTIGAR [6, 10]
- Is our implementation competitive? ✓



Eval: KIPDR versus Data-Flow Techniques

- Four k-induction-based configurations
- Manually crafted examples (click on program to open), on which k-induction alone does not succeed
- In-depth discussion of the examples in technical report [2]
- 'T' means time limit, 'M' means memory limit exceeded

Task	KI←DF Boxes	KI←DF Boxes, Eq	KI←DF Boxes, Eq, Mod2	KI←⟲←KIPDR
const.c	3.3 s	3.3 s	**3.2 s**	3.8 s
eq1.c	T	**3.2 s**	3.3 s	4.9 s
eq2.c	M	M	M	**3.9 s**
even.c	T	T	**3.5 s**	3.9 s
odd.c	T	T	**3.4 s**	4.1 s
mod4.c	T	T	T	**3.6 s**
bin-suffix-5.c	M	M	M	**3.6 s**

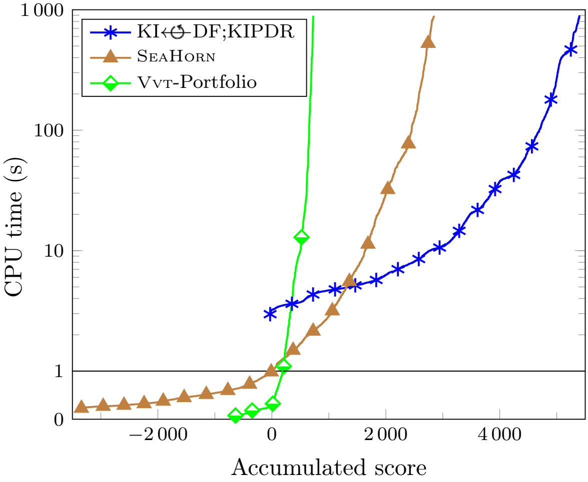
Eval: Comparison with Non-PDR Approaches

- Results of SV-COMP 2019 [1]
- Reports the six verifiers that performed best on those problems
- 'T' means time limit, 'O' means verifier gave up

Task	SV-COMP 2019						KI⟲KIPDR
	SKINK	UAUTOMIZER	UKOJAK	UTAIPAN	VERIABS	VIAP	
`const.c`	4.2 s	8.7 s	9.1 s	8.2 s	13 s	110 s	**3.8 s**
`eq1.c`	290 s	7.8 s	7.6 s	8.3 s	14 s	57 s	**4.9 s**
`eq2.c`	4.1 s	8.1 s	8.6 s	7.6 s	14 s	4.7 s	**3.9 s**
`even.c`	**3.7 s**	7.4 s	8.2 s	8.6 s	140 s	4.5 s	3.9 s
`odd.c`	O	9.6 s	T	11 s	140 s	4.6 s	**4.1 s**
`mod4.c`	4.0 s	8.4 s	8.4 s	7.7 s	140 s	4.5 s	**3.6 s**
`bin-suffix-5.c`	O	14 s	T	13 s	13 s	4.7 s	**3.6 s**

Eval: Comparison with PDR-Based Verifiers

- Accumulated score of solved tasks



Conclusion

- Implementation of PDR for software that is
  - Open source
  - Reproducible
  - Competitive
  - Integrated in CPAchecker
- Reference implementation for comparison
- Usable as invariant generator
- Interesting example programs
- Artifact available [3]

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