Giving Some Pointers for Abstraction-Based Model Checking

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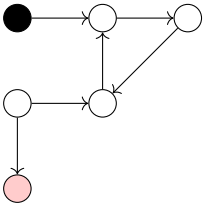
BME FACULTY OF ELECTRICAL ENGINEERING AND INFORMATICS
ftsrg Critical Systems Research Group

Abstraction in Verification



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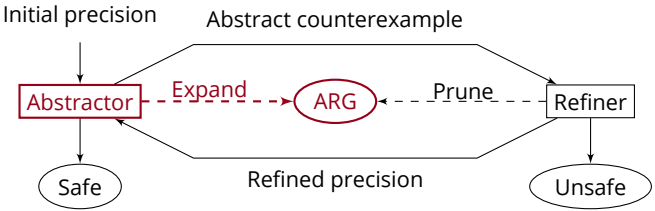
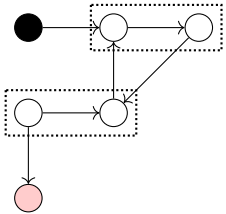
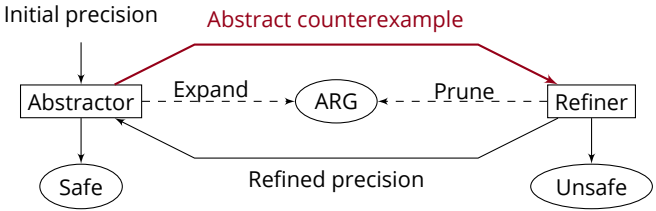
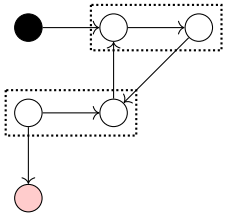




Abstract state space

Abstraction in Verification





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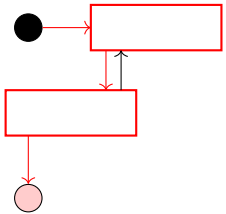
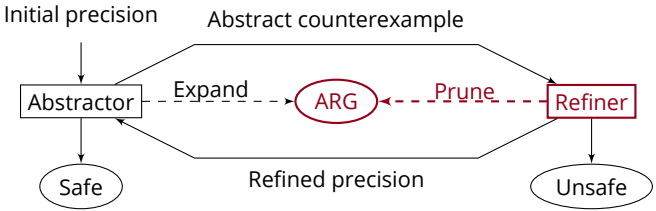
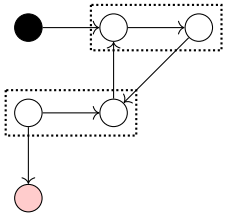


Abstract counterexample

Abstraction in Verification





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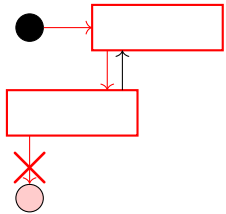

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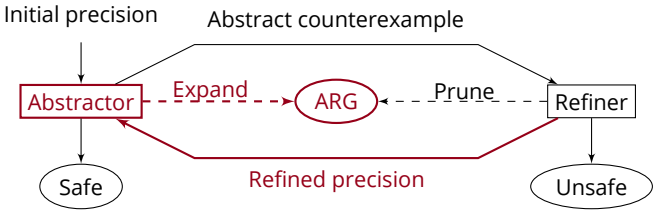

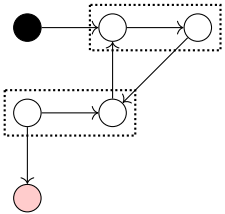

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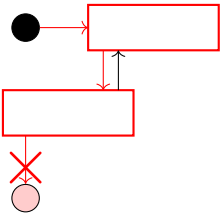

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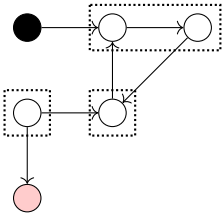
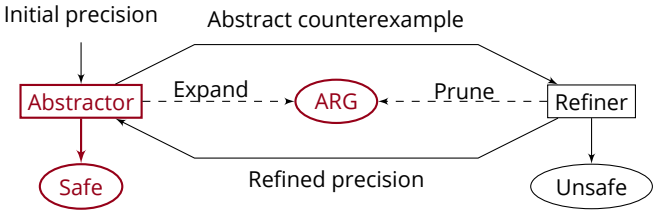
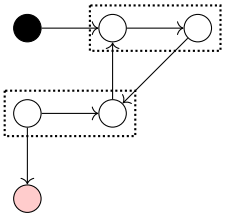


Refined abstract state space

Abstraction in Verification





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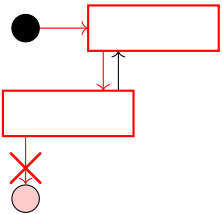

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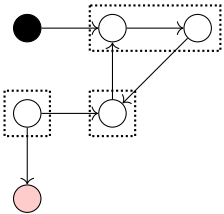

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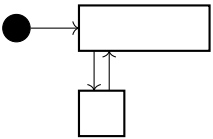
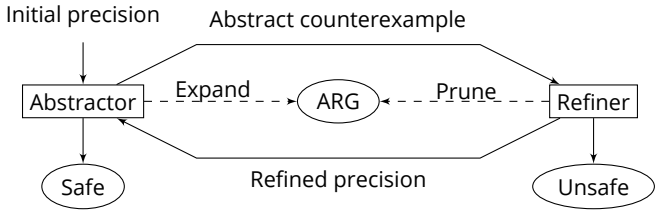
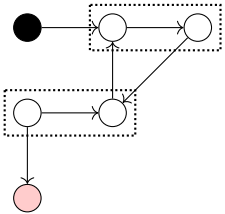


Safe ARG

Abstraction in Verification





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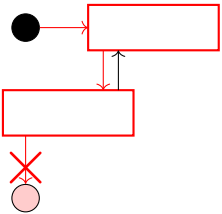

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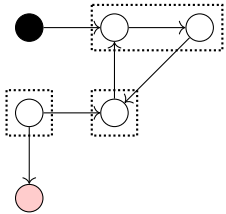

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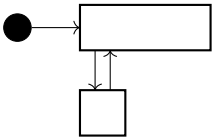

Safe ARG

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Ignoring Pointers

- Easy to implement
- Great for safety proofs (if lucky)
- Unsuitable for bug finding

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- Moderately complex to implement
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Rarely useful

Modeling Pointers Explicitly

- Moderately
- safety proofs
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Widespread tool support

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Plenty of research

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Summary of Contributions

Theoretical

- Precise, symbolic pointer analysis leveraging SMT solvers
- Extensible pointer analysis *plug-in* for CEGAR
- Examination of the effect of abstract domain choice

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- Precise, symbolic pointer analysis leveraging SMT solvers
- Extensible pointer analysis *plug-in* for CEGAR
- Examination of the effect of abstract domain choice

Practical

- Plug-In implementation in Θtheta
- Evaluation on software benchmarks

Pointers in Verification

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1 int a;
2 int b;
3 a = 0; b = 0;
4 int cond = nondet();
5 int *c =  cond?&a:&b;
6 int *d = !cond?&a:&b;
7 *c = 1;
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9 assert(a==1||b==1);
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Some nondeterministic input

Aliasing either a or b

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Dereference

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Contribution 1: Reference Elimination

Pointers in Verification

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1 (declare-fun deref (Int Int Int) Int)
  (declare-fun a () Int) (declare-fun b () Int) (declare-fun c () Int)
  (declare-fun d () Int) (declare-fun cond () Bool)

2 (assert (= a 0))
  (assert (= b 1))

3 (assert (= (deref a 0 1) 0)) (assert (= (deref b 0 1) 0))

4 (assert (= c (ite cond a b))) (assert (= d (ite (not cond) a b)))

5 (assert
      (let ((idx1 (+ 1 (ite (= c 1) 1 (ite (= c 0) 1 0)))))
      (let ((idx2 (+ 1 (ite (= d c) idx1 (ite (= d 1) 1 (ite (= d 0) 1 0))))))
      (and (= (deref c 0 idx1) 1)
           (= (deref d 0 idx2) 2)
6          (let ((idx3 (ite (= 0 d) idx2 (ite (= 0 c) idx1 1))))
           (let ((idx4 (ite (= 1 d) idx2 (ite (= 1 c) idx1 1))))
           (or (= (deref a 0 idx3) 1)
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deref
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Dereference:
(ptr, offset, idx) -> value

Pointers in Verification

deref UF

Unique address

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1(b)	0	1	0
0(a, c)	0	2	**1**

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ptr	*off*	*idx*	(*deref ptr off idx*)
0(a)	0	1	0
1(b)	0	1	0
1(b, c)	0	2	**1**

$c == b$

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Dereference:
(ptr, offset, idx) -> value

Pointers in Verification

ptr	*off*	*idx*	(*deref ptr off idx*)
0(a)	0	1	0
1(b)	0	1	0
0(a, c)	0	2	**1**
1(b, d)	0	2	**2**

$c == a$

$d == b$

ptr	*off*	*idx*	(*deref ptr off idx*)
0(a)	0	1	0
1(b)	0	1	0
1(b, c)	0	2	**1**
0(a, d)	0	2	**2**

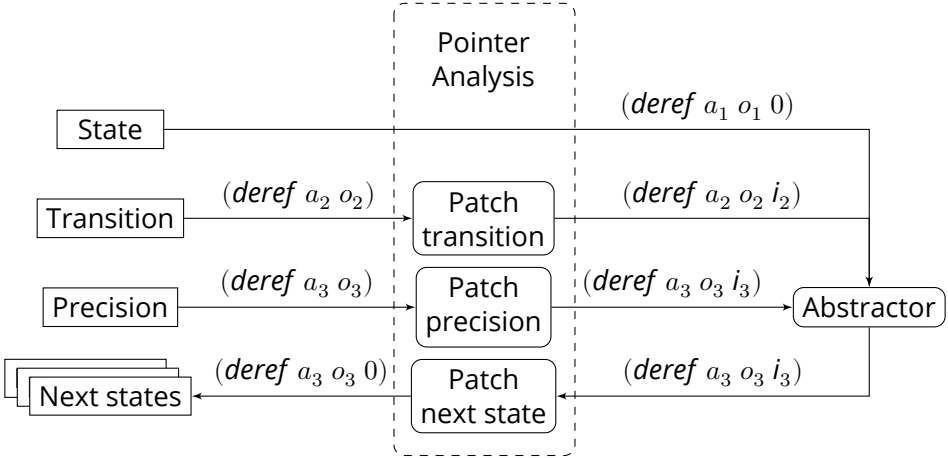
$c == b$

$d == a$

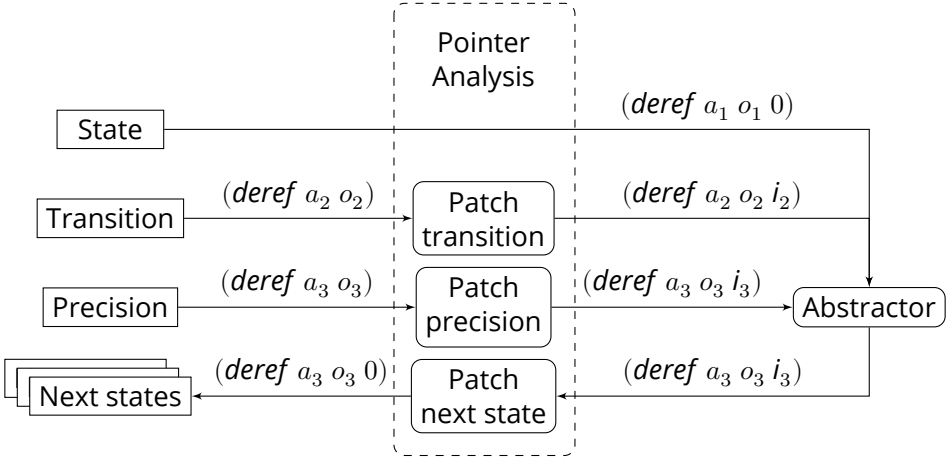
```
1 int *a = malloc();
2 int *b = malloc();
3 *a = 0; *b = 0;
4 int cond = nondet();
5 int *c =  cond?a:b;
6 int *d = !cond?a:b;
7 *c = 1;
8 *d = 2;
9 assert(*a==1||*b==1);
```

Dereference:
(ptr, offset, idx) -> value

CEGAR Plug-In



CEGAR Plug-In



Contribution 2: CEGAR Plug-In

Experiments

Implementation in Θ*theta*

- As an independent plug-in
- Supports any abstract domain and all refinement strategies

? Better than *havoc*?

? Which domain is best?

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- 633 *reachability* tasks from SV-Benchmarks
- BenchExec for accuracy

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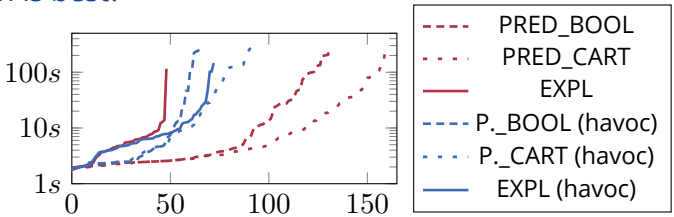

Experiments

Implementation in Θ*theta*

- As an independent plug-in
- Supports any abstract domain and all refinement strategies

? Better than *havoc*? **Yes!**

? Which domain is best? **Predicate**

Experiments on Benchmarks

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