

HSF(C): A Software Verifier based on Horn Clauses

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Developing verifiers today

Program Model

transition system, program with procedures,
multi-threaded program, functional program, ...

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Proof Rule

Invariance, summarization, rely/guarantee,
transition invariance, refinement typing, ...

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Complex verification effort

=

Verification Tool

Developing verifiers tomorrow

Verification Tool = Synthesizer (Program Model, Proof Rule)

Proof rules

$$\begin{aligned} & \text{Init}(V) \rightarrow \text{Inv}(V) \\ & \text{Inv}(V) \wedge \text{Step}(V, V') \rightarrow \text{Inv}(V') \\ & \text{Inv}(V) \wedge \text{Error}(V) \rightarrow \perp \end{aligned}$$

Transition system is safe

$$\begin{aligned} & \text{Inv}(V) \wedge \text{Step}(V, V') \rightarrow \text{TransInv}(V, V') \\ & \text{TransInv}(V, V') \wedge \text{Step}(V', V'') \rightarrow \\ & \quad \text{TransInv}(V, V'') \\ & \text{dwf}(\text{TransInv}(V, V')) \end{aligned}$$

Transition system terminates

$$\begin{aligned} & \text{Init}(V) \wedge V'=V \rightarrow \text{Summ}(V, V') \\ & \text{Summ}(V, V') \wedge \text{Step}(V', V'') \rightarrow \text{Summ}(V, V'') \\ & \text{Summ}(V, V') \wedge \text{Call}(V', V'') \wedge V'''=V'' \rightarrow \text{Summ}(V'', V''') \\ & \text{Summ}(V, V') \wedge \text{Call}(V', V'') \wedge \text{Summ}(V'', V''') \wedge \\ & \quad \text{Return}(V''', V''') \wedge \text{Local}(V', V''') \rightarrow \text{Summ}(V, V''') \\ & \text{Summ}(V, V') \wedge \text{Error}(V) \rightarrow \perp \end{aligned}$$

Procedural program is safe

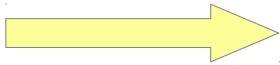
$$\begin{aligned} & \text{Init}(V) \rightarrow \text{Inv}_i(V) \\ & \text{Inv}_i(V) \wedge \text{Step}_i(V, V') \rightarrow \text{Inv}_i(V') \\ & (\forall \text{Inv}_i(V) \wedge \text{Step}_i(V, V')) \rightarrow \text{Env}_j(V, V') \\ & \text{Inv}_i(V) \wedge \text{Env}_j(V, V') \rightarrow \text{Inv}_i(V') \\ & \text{Inv}_1(V) \wedge \dots \wedge \text{Inv}_N(V) \wedge \text{Error}(V) \rightarrow \perp \end{aligned}$$

Multi-threaded program is safe

HSF(C)

- C frontend based on CIL [Necula-et-al, CC 2002]
 - translates input program to Horn clauses
- Summarization proof rule [Reps, Horwitz, Sagiv - POPL 1995]
- HSF algorithm
[Grebenshchikov, Lopes, Popeea, Rybalchenko - PLDI 2012]

Competition candidate	CEGAR	Predicate Abstraction	Bounded Model Checking	Shape Analysis	ART-based Analysis	Lazy Abstraction	Interpolation	Concurrency Support
BLAST	✓	✓			✓	✓	✓	
CPA-ABE	✓	✓			✓	✓	✓	
CPA-MEMO	✓	✓			✓	✓	✓	
ESBMC			✓					✓
FSHELL			✓					
LLBMC			✓					
PREDATOR				✓				
QARMC-HSF(C)	✓	✓			✓		✓	✓
SATABS	✓	✓						✓
WOLVERINE	✓				✓	✓	✓	



HSF(C) results

ControlFlowInteger category:
· 96 benchmarks

Place	Tool	Points (144 max)
1st	CPAChecker-ABE	141
2nd	CPAChecker-Memo	140
3rd	HSF(C)	140
4th	ESBMC	102

94 correct results in 80 minutes
2 time/outs

HSF and related work

- Software verification tools
 - Slam, Blast, Terminator, CPAchecker, DSolve
- Verifiers - target for automated synthesis
 - XSB: generates model checkers for CCS programs
 - Getafix: generates model checkers for boolean programs

HSF: generates model checkers for C and OCaml programs
competitive with mature software verification tools

Synthesizing software verifiers from proof rules
[Grebenshchikov, Lopes, Popeea, Rybalchenko - PLDI 2012]₈

Questions?