Karlsruhe Institute of Technology

Technische Universität München

Quis Custodiet Ipsos Custodes?

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PROGRAMMING PARADIGMS GROUP

```
theorem nonInterferenceSecurity:
  assumes "[cf₁] ≈L [cf₂]" and "(-High-) ∉ ⌊HRB-slice (CFG-node (-Low-))⌋CFG" and "valid-edge a"
  and "sourcenode a = (-High-)" and "targetnode a = n" and "kind a = (λs. True)√" and "n ≜ c"
  and "final c'" and "⟨c,[cf₁]⟩ ⇒ ⟨c',s₁⟩" and "⟨c,[cf₂]⟩ ⇒ ⟨c',s₂⟩"
  shows "s₁ ≈L s₂"
proof -
  from High-target-Entry-edge obtain ax where "valid-edge ax" and "sourcenode ax = (-Entry-)"
    and "targetnode ax = (-High-)" and "kind ax = (λs. True)√" by blast
  from `n ≜ c` `⟨c,[cf₁]⟩ ⇒ ⟨c',s₁⟩` obtain n₁ as₁ cfs₁ where "n -as₁→√* n₁" and "n₁ ≜ c'" and "preds (kinds as₁) [(cf₁,undefined)]"
    and "transfers (kinds as₁) [(cf₁,undefined)] = cfs₁" and "map fst cfs₁ = s₁" by(fastsimp dest:fundamental-property)
  from `n -as₁→√* n₁` `valid-edge a` `sourcenode a = (-High-)` `targetnode a = n` `kind a = (λs. True)√`
  have "(-High-) -a#as₁→√* n₁" by(fastsimp intro:Cons-path simp:vp-def valid-path-def)
  from `final c'` `n₁ ≜ c'` obtain a₁ where "valid-edge a₁" and "sourcenode a₁ = n₁" and "targetnode a₁ = (-Low-)" and "kind a₁ = ⇑id"
    by(fastsimp dest:final-edge-Low)
```

Quis Custodiet Ipsos Custodes? [Juvenal]

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Who will guard the Guards?

Many software security analysis algorithms are published without soundness proof, some with a manual proof only

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Who will guard the Guards?
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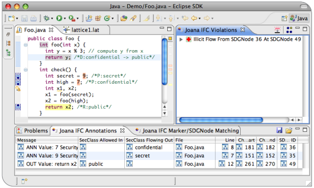
Vision of our Project:

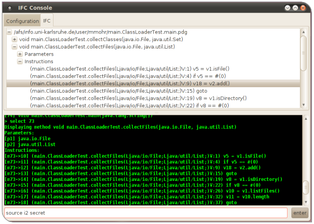
- provide machine-checked proofs for IFC algorithms
- reach a new level of reliability in language based security (LBS)
- develop new techniques to validate the underlying language description
- integrate semantics, theorem provers and program analysis with LBS

Ultimate Goal: automatically generate an executable, completely machine-verified, PDG-based IFC tool

Starting Point and Goals

KIT: Joana
PDG-based IFC for Java





TUM: Jinja
Java semantics in Isabelle

Starting Point and Goals

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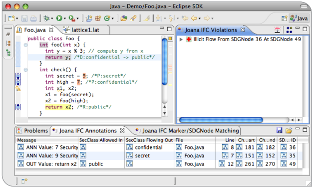
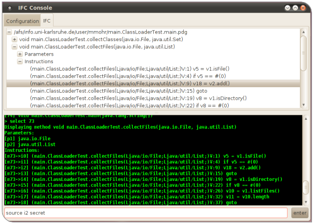
PDG-based IFC for Java





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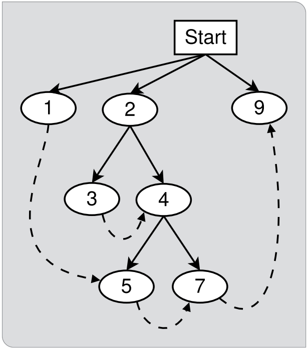
Project Idea

1. verify the PDG-based IFC algorithm using Isabelle
2. support verification by innovative counter example generators

A tiny PDG

```
a = input();
while (n>0) {
  x = input();
  if (x>0)
    b = a;
  else
    c = b;
}
z = c;
```



Slicing Theorem:

no path $x \to^* y \implies$ information flow $x \to y$ impossible

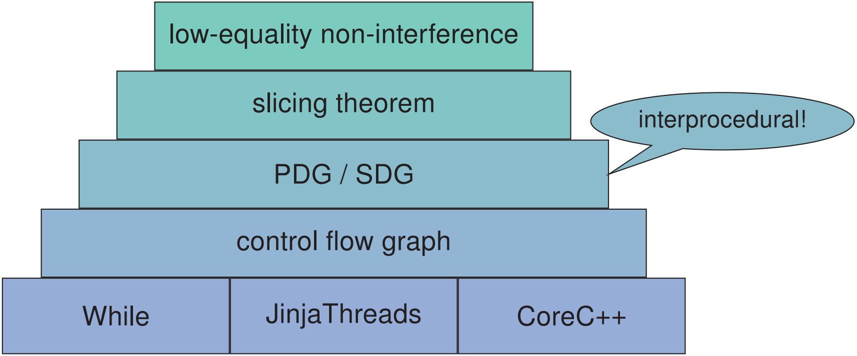
$\exists$ path $x \to^* y \implies$ potential information flow $x \to y$

Precise PDG construction for full Java is very complex

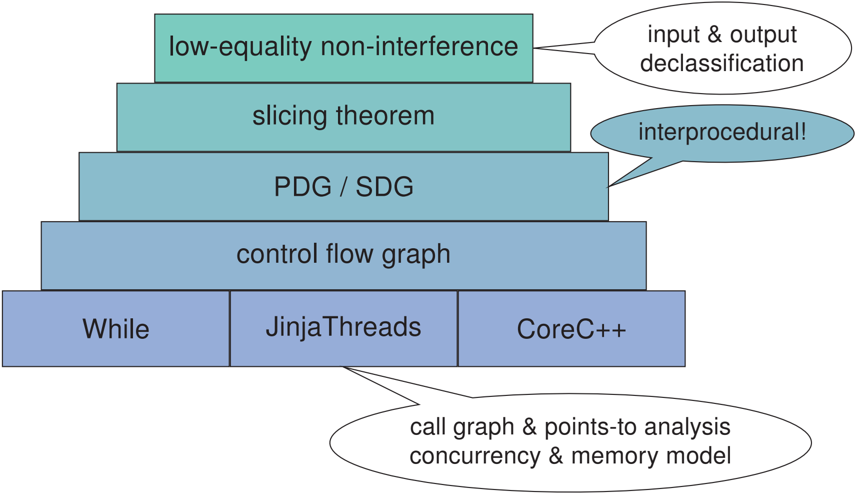
requires precise points-to analysis

scales to ca. 100 kLOC

Interprocedural PDG-based IFC is correct



Interprocedural PDG-based IFC is correct



Counter-Example Generation

Idea: Find errors in defintions & theorems early
Generate counter-examples for incorrect theorems automatically!

Nitpick
translate HOL formula to propositional logic
hand it to a SAT solver

generally applicable, requires a lot of fine tuning

Quickcheck
evaluate the formula
test data generation:

- random
- exhaustive with intelligent generators
- symbolic execution + narrowing

fast, but requires executability

Results

KIT:

- PDGs & slicing for full Java bytecode
  [FSE ’03, PASTE ’04, SCAM ’07a, TPHOLs’ 08, Hamm ’09, JASE ’09a]
- path conditions in PDGs: necessary conditions for information flow
  [SAS ’96, ICSE ’02, TOSEM ’06, SCAM ’07b, PLAS ’08, JASE ’09b]
- IFC for full Java based on PDGs
  [ISSSE ’06, ISOLA ’06, PLAS ’08, IJIS ’09, PLAS ’09, Verify ’10]
- Semantics for Java and C++
  [OOPSLA ’06, FOOL ’08, ESOP ’10, ITP ’11]

TUM:

- Nitpick
  [TAP ’09, TAP ’10, ITP ’10, IJCAR ’10, LPAR ’10, PPDP ’11, FroCoS ’11]
- Quickcheck
  [SEFM ’03, TPHOLs ’09, ICLP ’11, ITP ’11, FroCoS ’11]

Ongoing Work in Quis Custodiet

- Isabelle proof for full algorithm including points-to, threads & memory model
- automatically generate an executable, completely machine-verified, PDG-based IFC tool
- extend and engineer Nitpick & Quickcheck application to Quis Custodiet theorems

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Isabelle!