The Final Step in the Evolution of Programming

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Grad Orientation '12

The Evolution of Programming

Machine code, Assembly language.

Procedural abstraction, Structured programming.

Fortran, LISP, Cobol, Algol (1950s-1960s)
C (early 1970s)

Object-orientation

Simula, Smalltalk (1960s-1970s)

Typed Functional Programming

ML (early 1970s)

Logic Programming

Prolog (early 1970s)

Tweaking

C++, Scheme, Java, Standard ML (1980s)

More Tweaking

Haskell, OCaml, Scala, Python (1990s-2000s)

If We're Just Tweaking...

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We must be done!

[Celebrate here]

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We must be done!

[Celebrate here]

But then why is software still so hard to write?

Computing systems are doing so much:

Why can't we guarantee they work?

We believe that correctness is

the final frontier of programming.

How to Tackle Correctness?

- Mainstream languages:
  - Types (weak, but fully automatic).
  - Assertions (expressive run-time checks).
  - Testing (cannot show absence of bugs).
- Research languages and systems:
  - Model-checking (symbolic exhaustive testing).
  - Theorem proving (use computer proofs to show no bugs).
  - Advanced type systems (rich types express properties).

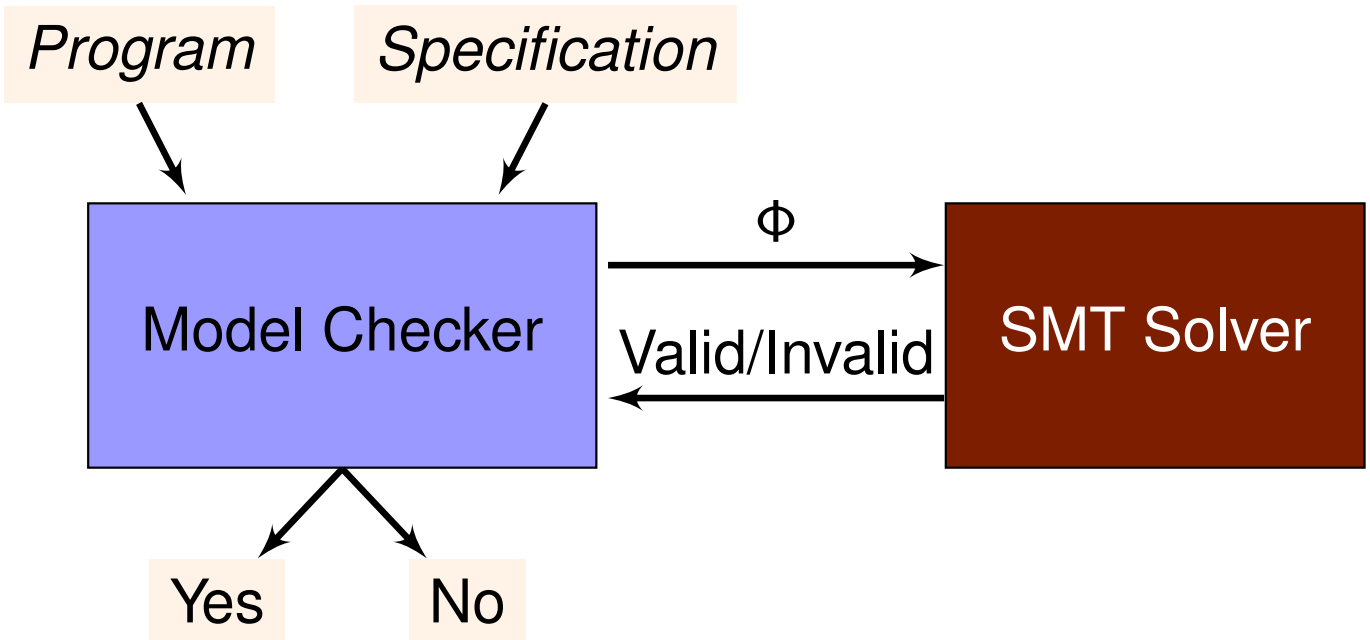
The Computational Logic Center at U. Iowa

- People:
  - Led by Prof. Stump, Prof. Tinelli.
  - Postdocs: Dr. Christoph Sticksel, Dr. Francois Bobot
  - Doctoral students: Mohammad Aziz, Frank (Peng) Fu, Tianyi Liang, Andy Reynolds, Harley Eades.
  - Master's students: Ruoyu Zhang.
  - Undergraduates: Angello Astorga.
  - Recent alumni: Dr. Duckki Oe (postdoc MIT), Dr. Garrin Kimmell (Kestrel Institute), Dr. Teme Kahsai (Skype).
- Collaborations:
  - CMU, NICTA (Australia), Minnesota, NYU, U. Penn., Portland State, JAIST (Japan)
  - Microsoft Research, Intel, Onera (France), Rockwell-Collins, Skype.
- Funding:
  - National Science Foundation, Air Force Office of Scientific Research, Intel, Rockwell-Collins.

Main focus: program verification via applied logic

Automatic Verification

- Goal: automatically prove properties about real code.
- Main techniques: model-checking and SMT.
- Important in industry, academia (Turing award 2007).



- KIND model-checker.
  - Prof. Tinelli, Dr. Jed Hagen (now at NASA), Dr. Ge (now at Two Sigma), Dr. Kahsai (now at Skype), Dr. Sticksel.
  - In use at Rockwell-Collins.

Verified-Programming Languages

- Existing languages use types to catch simple bugs.
  - No: `34 + "hi"`
  - No: `34("hi")`
- Fancier languages => fancier type systems.
  - JAVA, C#: generics.
  - HASKELL: polymorphism, type classes.
  - SCALA: mixins, implicits.
- Even more expressive: dependent types.
  - `list A ==> list A n`
  - `["a", "b", "c"] : list string 3`
  - `append : list A n -> list A m -> list A (n+m)`
  - Programs may contain proofs (e.g. that `n+m = m+n`).
- TRELLYS.
  - Prof. Stump, Harley Eades, Frank (Peng) Fu, Angello Astorga.
  - Building on previous work on GURU.

How You Can Learn More

- 22c:196:002, Lambda Calculus and Applications
  - Dr. Stump, MW, 2:00–3:15pm, English-Philosophy Building, Room 402.
  - Lambda calculus, including dependent type systems.
  - Foundation for functional programming, computer-checked proofs.
- 22c:188, Logic in Computer Science.
  - Dr. Sticksel, MWF, 11:30A–12:20pm, MacLean Hall, Room 105.
  - Propositional, predicate, temporal, and modal logics.
  - Knowledge representation and reasoning.
- Reading group on automated reasoning.
  - Fridays 2:00–3:30pm, starting August 31st.
  - Talk to us for more information.
- Talk to us or our students.

The Final Step

- Programming language evolution has plateaued.
- Building reliable software is a crucial challenge.
- Verification, verified-programming languages are the next step.
- The U. Iowa CLC is ready.
  - Logic.
  - Automatic Verification.
  - Verified-Programming Languages.
- We invite you to get involved!