Interactive Formal Verification

Welcome

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Academic year 2017–2018
Course usually lectured by Prof. Lawrence Paulson

Sabattical leave this year
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My office: FS16

• Until start of November
• Then at ARM, but will return to finish course

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Administrivia

Course website:

https://www.cl.cam.ac.uk/teaching/1718/L21/
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Course consists of 16 hours of contact time:

- 12 hours of lab-based lecturing,
- 4 hours of lab-based practicals
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Assessed via two practical exercises:

- First (computer science) on parser combinators
- Second (maths) on metric spaces
IMPORTANT

All lecturing materials developed using Isabelle2016-1
Isabelle2017 about to be released imminently
Make sure you use Isabelle2016-1 for this course!
I recommend you install a local copy (ASAP) to follow along
Obtaining Isabelle

For your own machines: check course website

For lab machines see:

/auto/groups/acs-software/L21/Isabelle2016-1/

Contains **Isabelle2016-1_app.tar.gz** for installation in home directory

Also can start Isabelle2016-1 from your machine via:

/auto/groups/acs-software/L21/Isabelle2016-1/
Isabelle2016-1/Isabelle2016-1
Free! See:

http://concrete-semantics.org/

A stripped down version is distributed with Isabelle
Motivation
Developing software is hard

Most software (and hardware) has bugs

Bugs are costly, and potentially dangerous
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*IDEA*: treat program as a formal mathematical object

Prove relevant properties about model and obtain certified implementation thereafter
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Increases confidence in software/hardware implementation
Writing and checking proofs is hard

Proofs in mathematics and computer science may:

• Be tedious to check
• Contain subtle mistakes
• Be controversial (due to e.g. size, inability to review adequately)
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Increases confidence in proof
Interactive theorem proving

Want to work in an expressive logic (which?)
Interactive theorem proving

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The more expressive our logic the worse it behaves computationally

Proof search undecidable, intractable even in decidable fragments
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IDEA: have the computer and a human work together

Human guides the proof search with computer:

- Checking that the human’s reasoning is valid
- Helping when it can: (semi-)decision procedures, counterexample finders...
Isabelle, and Isabelle/HOL
Isabelle: a generic proof assistant

Isabelle initially written by Paulson starting mid 80s

Nipkow, Wenzel and others in Munich and elsewhere now a major development force

Written in Standard ML, follows LCF design philosophy
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Isabelle is a logical framework:

- Provides a relatively weak base (meta) logic
- More interesting (object) logics can be embedded in it
- Provides common reasoning tools, document preparation, and so on
Many different object logic embeddings:

- ZF set theory
- First-order logic
- Martin-Löf type theory
Many instantiations

Many different object logic embeddings:

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- Martin-Löf type theory

In this course:

- (Mostly) ignore Isabelle’s status as a logical framework
- Focus on one object logic: HOL
- Show off Isabelle/HOL as an interactive proof assistant for HOL
Gordon’s higher-order logic (HOL)

HOL = Church’s Simple Theory of Types + type polymorphism
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Suggested by Mike Gordon as a suitable logic for hardware verification

Implemented in HOL4, HOL Light, ProofPower HOL, HOL Zero
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HOL = Church’s Simple Theory of Types + type polymorphism

Suggested by Mike Gordon as a suitable logic for hardware verification

Implemented in HOL4, HOL Light, ProofPower HOL, HOL Zero

...and of course Isabelle/HOL
HOL as a logic:

- Is polymorphically typed (as opposed to e.g. ACL2)
- Does not have type-dependency (as opposed to e.g. Coq or Agda)
- Is higher-order (as opposed to e.g. ACL2, or tools like Vampire)
- Strikes a good middle ground between expressivity and ability to interact with external tools (e.g. FOTPs, SMT solvers, etc.)
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As a functional programmer HOL will “feel” very familiar

No need to learn a radically different way of doing things
First taste of Isabelle/HOL
See associated theory...