The University of Manchester

COMP60332: Automated Reasoning and Verification

Konstantin Korovin and Renate Schmidt

Theme: Ontology Engineering and Automated Reasoning

Outline

Reasoning

Reasoning is the main ingredient of any intellectual activity.

The main challenge: how to automate the reasoning process.

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Automated Reasoning

- What is Reasoning? Solving problems by syntactic manipulations.

Software: Does your program accesses unallocated memory?

Math: Does this equation $(xy)^{-1} = y^{-1}x^{-1}$ hold in all groups?

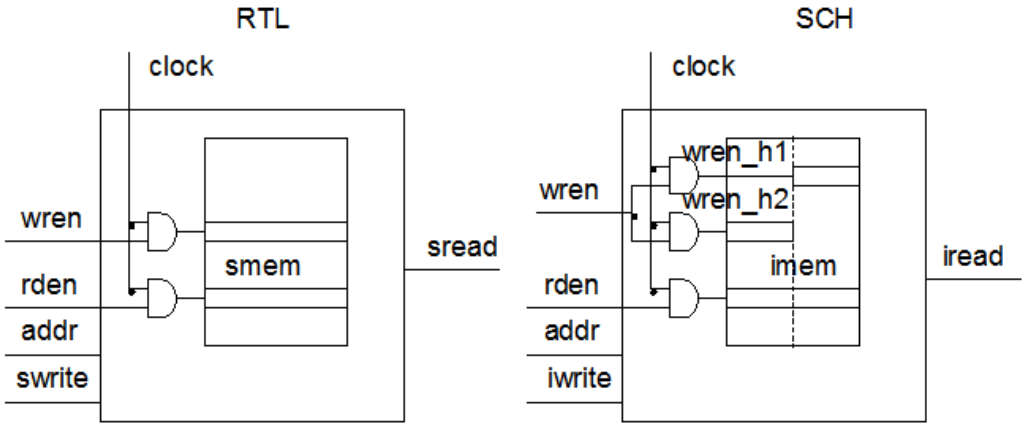
Knowledge management:
Can we represent and analyse all available knowledge about human body ?

Automated reasoning: can we solve all these problems automatically ?

Automated Reasoning

- What is Reasoning? Solving problems by syntactic manipulations.

  Hardware: Are these two hardware designs equivalent?



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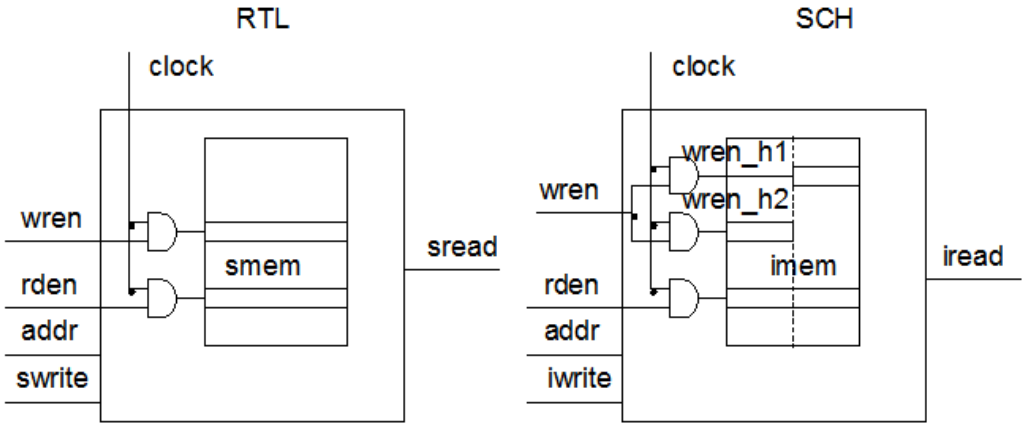

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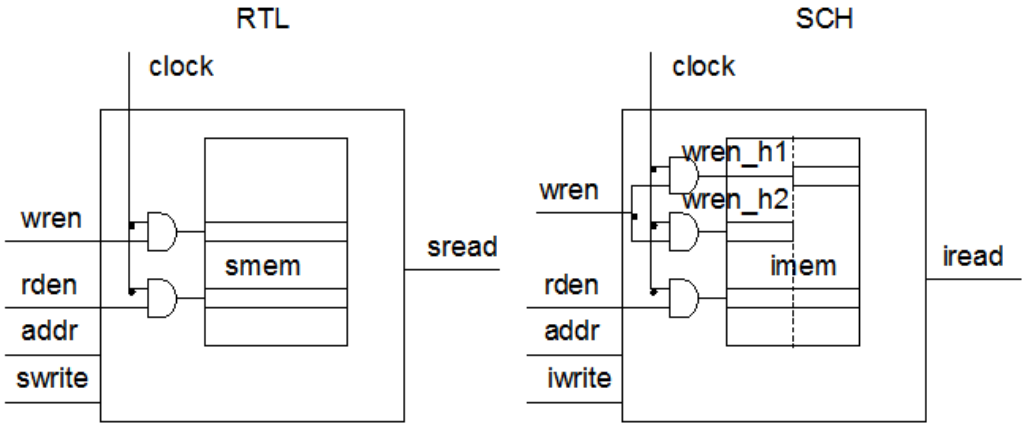

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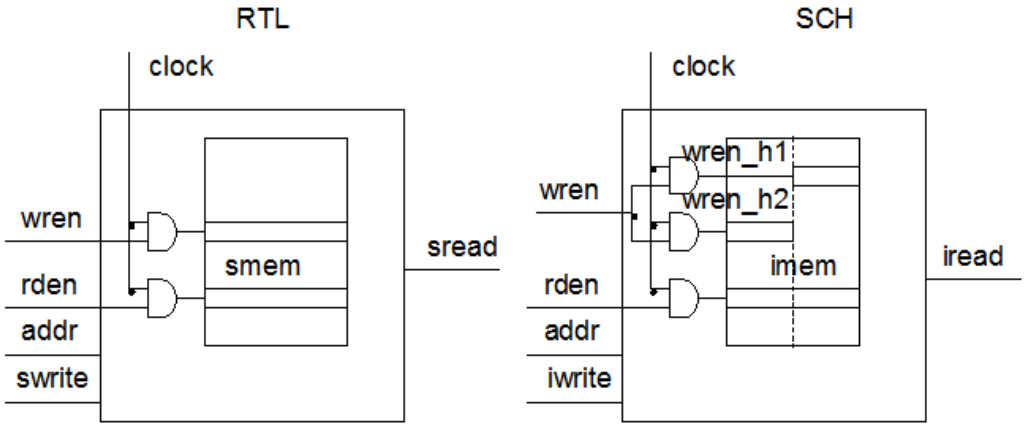

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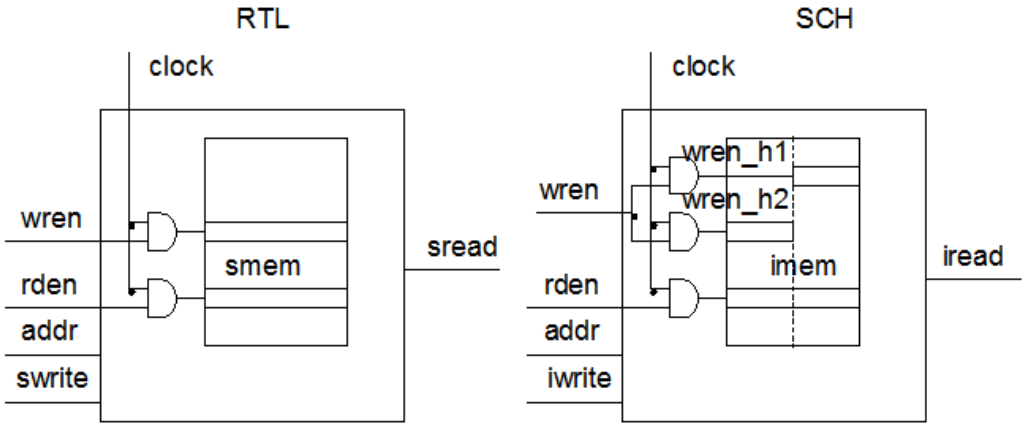

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The scale of automation required

Intel floating arithmetic bug cost $475 million.

Intel i7 Haswell-E 2,600,000,000 gates

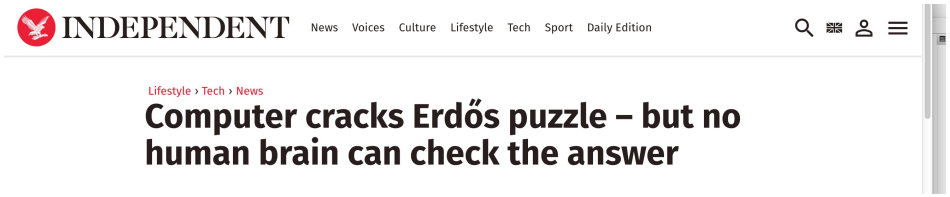
Software bugs cost billions.

40 Mil LOC

Major companies: Intel, Microsoft, Airbus, NASA intensively use formal methods.

In mathematics

Erdős discrepancy problem proved by a SAT solver (2014):



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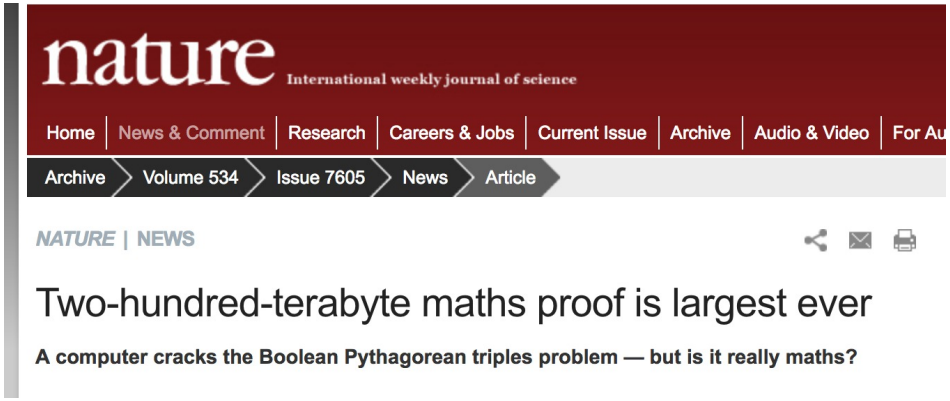
Largest math proof ever: Pythagorean triples problem was proved by a SAT solver (2016)



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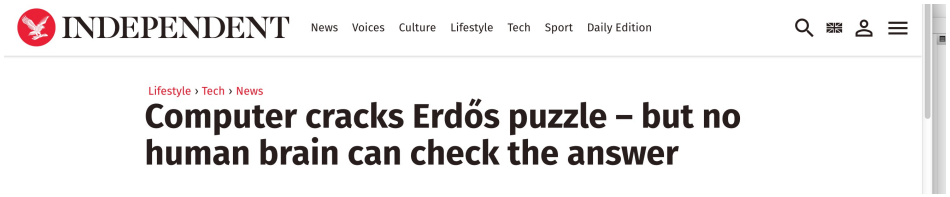

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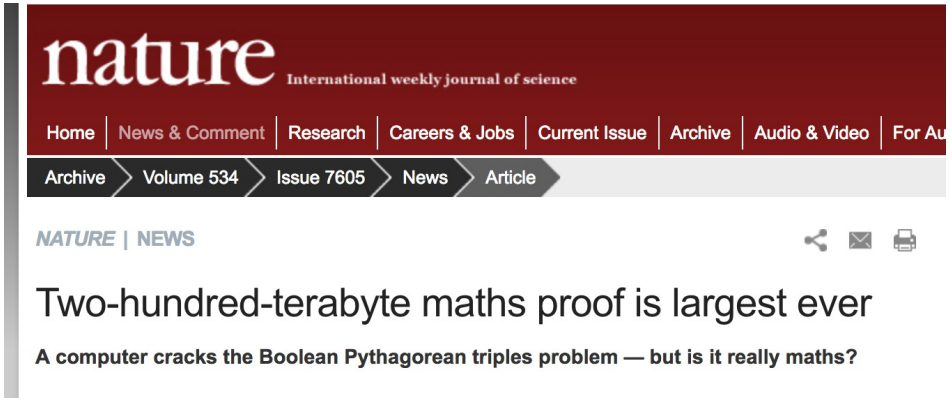

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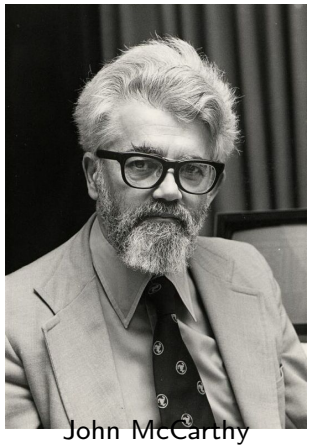
Applications of automated reasoning

Applications:

- software and hardware verification: Intel, Microsoft
- information management: biomedical ontologies, semantic Web, databases
- combinatorial reasoning: constraint satisfaction, planning, scheduling
- Internet security
- Theorem proving in mathematics



John McCarthy

"It is reasonable to hope that the relationship between computation and mathematical logic will be as fruitful in the next century as that between analysis and physics in the past." McCarthy, 1963.

Manchester: world leading in logic and reasoning

- Theory:
  - first-order reasoning
  - resolution, superposition, instantiation, tableaux, linear arithmetic
  - ontology reasoning
- Applications:
  - software/hardware verification
  - semantic Web, bio-health
  - multi-agent systems
- Reasoning systems developed in our School:
  - iProver – an instantiation-based reasoner for first-order logic won major of awards at CASC championships.
  - Vampire – a superposition-based reasoner for first-order logic, won major awards at CASC championships.
  - MSPASS – a resolution/superposition based reasoner SPASS extended with reasoning with modal logics.
  - Fact++ an ontology reasoner: OWL DL.
  - Pellet an ontology reasoner: OWL DL.

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The approach:

- Formalise problems: using logic
- Solve problems: using efficient automated reasoning

Syllabus:

- Propositional logic: syntax, semantics, CNF transformation
- Propositional reasoning: DPLL algorithm: unit propagation, backjumping, lemma learning

- First-order logic: syntax, semantics, Skolemization
- First-order reasoning: resolution, completeness, redundancy elimination

- Applications: verification of transition systems, LTL, bounded and unbounded model checking

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Assessment

This course is self-contained, no prerequisites but assumes that students are comfortable with mathematical notions.

Exam: 50%

Closed book, 2 hours, choose 3 out of 4 questions

Coursework and lab: 50%

Assessed and unassessed exercises: pen and paper

Labwork involving

- SAT solvers
- first-order reasoning systems

Questions? please email:

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korovin@cs.man.ac.uk

Renate Schmidt (room 2.42)
schmidt@cs.man.ac.uk

Theme: Ontology Engineering and Automated Reasoning

Semester 2

Period	Course units
P3	COMP60332 – Automated Reasoning and Verification Konstantin Korovin and Renate Schmidt
P4	COMP62342 – Ontology Engineering for the Semantic Web Sean Bechhofer and Uli Sattler

Teaching day: Friday
Lectures: 2.15

Some advice on choosing themes

The Ontology Engineering and Automated Reasoning theme can be combined with any other theme

Has no prerequisites, no pre/co-requisite to any theme

It goes well with these themes

- Advanced Web Technologies
- Data Engineering
- Learning from Data
- Managing Data
- Parallel Computing in the Multi-Core Era
- Security
- Software Engineering 1-2

Core theme in: Semantic Technologies, Data and Knowledge Management and Artificial Intelligence pathways