COMP60121
Automated Reasoning

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Why Automated Reasoning?

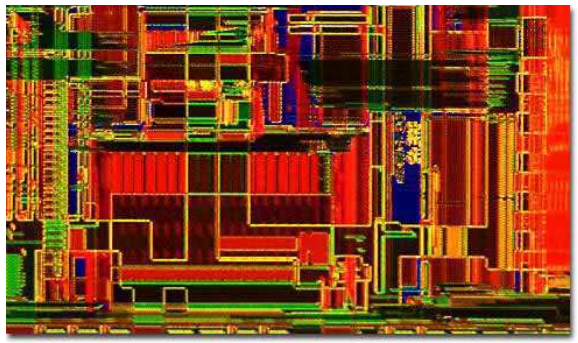
- Artificial Intelligence, Mathematics, Philosophy, Linguistics

  Robbins Algebra Problem, Oct. 1996

http://www.nytimes.com/

- Software + hardware verification, safety critical applications

  The Pentium Bug



http://micro.magnet.fsu.edu

  Ariane 5 Failure, 4.6.1996

http://www.dutchspace.nl/

- Web and agent technologies

Why You May Wish To Take COMP60121

- Inform/support other MSc course units (but not pre/co-requisites):
  - COMP60161: Knowledge Representation and Reasoning
  - COMP60462: The Semantic Web: Ontologies and OWL
  - COMP60391: Computer Security
- MSc in Mathematical Logic and the Theory of Computation
- Core in ACS specialisations:
  - Formal Methods
  - Artificial Intelligence

Course Outline

When?

Period 1, Semester 1

Mondays

Where?

Lectures: 2.15

Labs: 2.25a

A Course of Two Halves:

I Logic, Introduction to AR, Logic Programming (AV)

II Advanced Automated Reasoning (RS)

Part I: Logic, AR and Logic Programming

- Propositional Logic (revision)
- First-order/Predicate Logic
- Propositional and First-order Reasoning using Resolution
- Logic Programming: Prolog

Reasoning Example

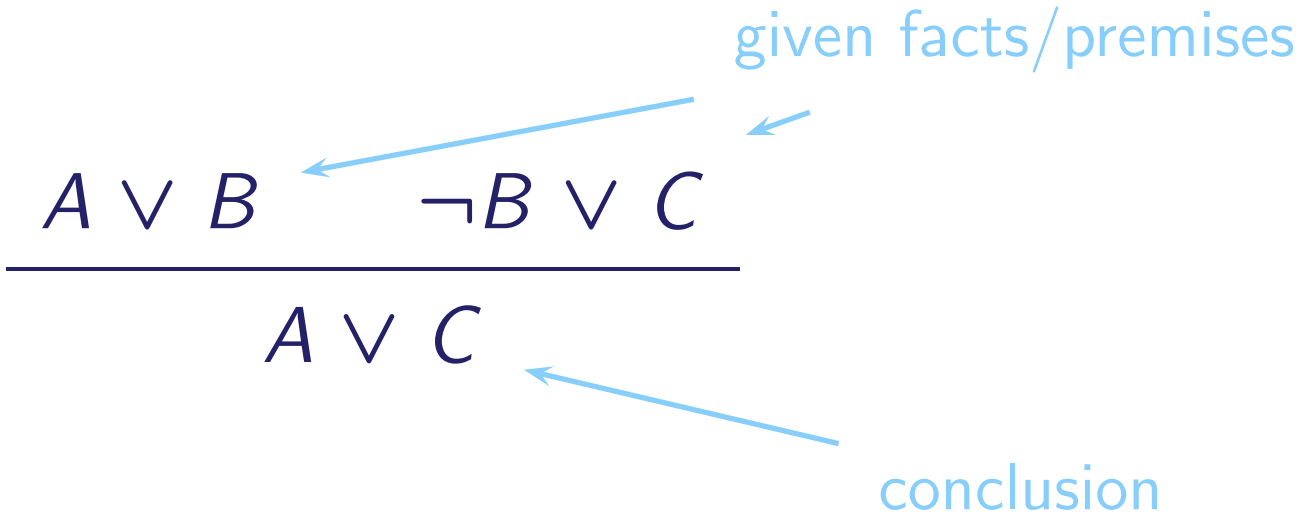
Given facts:

- If I live in Manchester then it is sunny
- If it is sunny then I need a hat

Conclusion:

- If I live in Manchester then I need a hat

The Resolution Principle



Basis for

- the best Automated Theorem Provers
  e.g. Vampire (Andrei), SPASS
- Logic Programming: e.g. Prolog

Logic Programming and Prolog

- Prolog Program — Rules and Facts:

```
has_ancestor(X,Y) :- has_parent(X,Y).
has_ancestor(X,Y) :-
    has_parent(X,Z), has_ancestor(Z,Y).

has_parent(roy,sue).
has_parent(sue,toby).
```

- Run program — Query:

```
?- has_ancestor(roy,X).

X = sue;
X = toby;
```

Part II: Advanced Techniques

Why?

- The unrestricted resolution calculus is very simple
  - Just two rules
  - Extremely prolific at generating new conclusions
  - Inefficient, impracticable
- Advanced techniques are available
- Part II is devoted to Introduction to Advanced Automated Reasoning

Modern Resolution Framework

- Avoid unnecessary inferences
- Powerful search control mechanisms
  - Orderings and selection functions
- General notion of redundancy
  - Simplification and optimisation techniques
- Optimised transformations into clausal form
- Has many uses and applications
  - This course: encryption key exchange protocol verfication

Teaching Format

Lectures:

- include Examples Classes
- paper-based Exercises (some assessed)

Labs:

- Approximately 35% of Teaching Time is lab
- Prolog
  - build a resolution theorem prover (last year)
- try out SPASS, Vampire

Pre-requisites

- Propositional Logic
- Knowledge of first-order logic and some logic programming experience would be some advantage, but is not essential

Not covered by lectures but part of first exercise sheet:

- Elementary set theory
  - What is a set, a relation, a function, set operations (intersection, union, etc), properties of binary relations (reflexivity, symmetry, transitivity, etc)
  - Exercise sheet available from course website

Reading List

- Recommended elementary level textbook:

  Kelly, J. (1997), *The Essence of Logic*. Prentice Hall.

- Recommended, more advanced:

  Schöning, U. (1989), *Logic for Computer Scientists.* Birkhäuser.

  Fitting, M. (1990), *First-Order Logic and Automated Theorem Proving*. Springer.

- See course unit description for more supplementary texts

Assessment

- Labs and coursework (30% Part I, 30% Part II)
- Examination (40%)
  - closed book