

MSc COMP6012

Automated Reasoning

Who, What, When, Where, Why?

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Why?

System Design:

- The Pentium Bug

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- The Pentium II Bug

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- Ariane 5 Failure, 4 June 1996

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- increasing design complexity . . .

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- software + hardware specification and design errors ...
- increasing design complexity ...
- Future: Internet encryption bug???...

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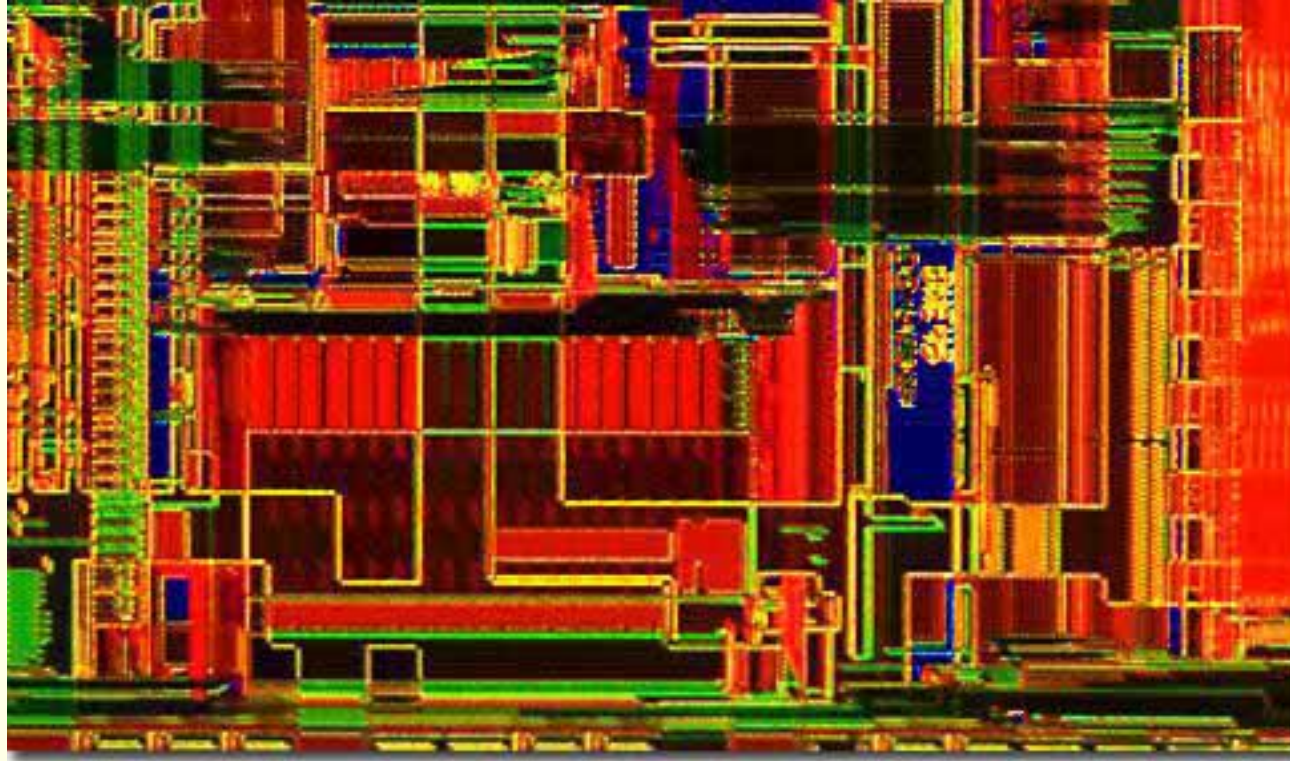
- The Pentium Bug
- The Pentium II Bug
- Ariane 5 Failure, 4 June 1996
- software + hardware specification and design errors . . .
- increasing design complexity . . .
- Future: Internet encryption bug???...hasn't been found...yet

Or...

- Mathematical Logical Foundations



<http://www.dutchspace.nl/>



<http://micro.magnet.fsu.edu>

Why You May Wish To Take COMP6012

- Inform/support other MSc course units (but not pre/co-requisites):
 - COMP6016: Knowledge Representation and Reasoning
 - COMP6039: Computer Security
 - COMP6046: The Semantic Web: Ontologies and OWL
- Mathematical Logic
- System Design: hardware, software, GRID, secure, biological. . .
- Design tool development: CAD, IDEs

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- (System property or component description via formal logic)
- Logical reasoning
- Automation: decision procedures
- Advanced techniques for efficiency
- Associated theoretical concepts, e.g. soundness and completeness

Course Outline

When?

Period 1, Semester 1

Mondays

Where?

Lectures: 2.15

Labs: 2.25a

A Course of Two Halves:

1. Formal Logic and Automated Reasoning (AJW)
2. Advanced Automated Reasoning (RenS)

Pre-requisites: Familiarity with Propositional Logic

Part I: Formal Logic and Automated Reasoning

- Classical Propositional Logic
- First-order Predicate Logic
- Automated Reasoning: Methods and Tools, including
 - resolution
 - logic programming

Reasoning Example

Assumptions:

Reasoning Example

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IF I live in MANCHESTER THEN it is SUNNY

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Reasoning Example

Assumptions:

IF I live in MANCHESTER THEN it is SUNNY

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Conclusion:

IF I live in MANCHESTER THEN I need an PARASOL

The Resolution Principle

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Assumptions: $(A \vee B)$ $(C \vee \neg B)$

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Conclusion: $(A \vee C)$

The basis of

- Automated Theorem-proving: e.g. Vampire (Andrei Voronkov)
- Logic Programming: e.g. Prolog

Logic Programming and Prolog

Prolog Program — rules and facts:

```
ancestor(X,Y) :- parent(X,Y) .
```

```
ancestor(X,Y) :- parent(X,Z) ,  
                  ancestor(Z,Y) .
```

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

Logic Programming and Prolog

Prolog Program — rules and facts:

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ancestor(X,Y) :- parent(X,Y).
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```
ancestor(X,Y) :- parent(X,Z),  
                  ancestor(Z,Y).
```

```
parent(sue,toby).
```

```
parent(roy,sue).
```

Run program:

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

```
X = sue;
```

```
X = toby;
```

Part II: Advanced Techniques

Why:

- The basic resolution calculus is very simple
 - Just two rules
 - Extremely prolific at generating new conclusions
 - Inefficient, impracticable

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Why:

- The basic 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 Advanced Automated Reasoning

Emphasis in Part II

- Introduction to advanced theorem proving
- Fundamentals of first-order resolution
 - Selection of important topics
 - Many examples and exercises

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- Introduction to advanced theorem proving
- Fundamentals of first-order resolution
 - Selection of important topics
 - Many examples and exercises
- Important basic properties of inference systems
 - Soundness $\rightsquigarrow$ no false conclusions are drawn
 - Completeness $\rightsquigarrow$ all true conclusions are drawn
 - Efficiency $\rightsquigarrow$ avoid unnecessary inferences

Modern Resolution Framework

- Best provers use resolution

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- Modern resolution framework = an extension of basic resolution calculus with:
 - Powerful search control mechanisms
 - ↪ ordering and selection refinements
 - General notion of redundancy
 - ↪ simplification and optimisation techniques
 - optimised transformations into clausal form

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- Best provers use resolution
- Modern resolution framework = an extension of basic resolution calculus with:
 - Powerful search control mechanisms
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 - General notion of redundancy
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 - optimised transformations into clausal form
- Has many uses and applications
 - This course: verification of Neuman-Stubblebine key exchange protocol
- Fast implementations: Vampire, (M)SPASS

Topics of Current Research

- Developing practical decision procedures
- Handling specific theories (equality, transitive relations, ...) or logics (description logics, modal logics, ...)
- Implementing fast automated theorem provers
- Relationship between different proof methods (resolution, tableau, ND, ...)
- Combining different proof methods and different provers
- Specific applications:
 - Software engineering
 - Ontologies and the semantic web
 - Multi-agent systems

Lectures:

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

Labs:

- Approximately 35% of Teaching Time is lab
- Prolog
 - build a resolution theorem-prover
 - extend with advanced techniques
- try out MSPASS, Vampire

Reading List

- 'Course Text':

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

- Recommended:

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

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

Assessment

- Examination (40%)
 - CLOSED book
- Exercises and labs (60%)