### Theme: Ontology Engineering and Automated Reasoning

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<td>COMP60332 – Automated Reasoning and Verification</td>
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- semester 2, periods P3/P4
- can be **combined with** any other theme
- has **no pre-requisite** themes
- **core theme** in Semantic Technologies, Data and Knowledge Management and Artificial Intelligence pathways
COMP60332: Automated Reasoning and Verification

Konstantin Korovin and Renate Schmidt

Theme: Ontology Engineering and Automated Reasoning
Data driven AI
- we don’t know problem structure
- we have data
- goal: learn the model that fits the data
- method: machine learning
- approximate and only as good as your data
- no explanations

Symbolic AI
- problem is formalised in logic
- we want to infer properties of the problem
- method: automated reasoning
- exact and general results
- detailed explanations – proofs

Learning vs Thinking
Automated Reasoning

What is Reasoning? Solving problems by syntactic manipulations.

Automated Reasoning

- symbolically represent the problem in logic
- solve the problem by applying symbolic rules to such representations
- automated reasoning – do this efficiently on large problems
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Formalise:

\[ \text{QRules} = \bigwedge (R \land C \land D) \]
\[ QPlaced_i = q_{i1} \lor \ldots \lor q_{in} \]
\[ QProblem = \text{QRules} \bigwedge_i QPlaced_i \]

Solve: automated reasoning (SAT solver)
Hardware verification

Are these two hardware designs equivalent?

Behaviour of such circuits can be represented as first-order formulas:

$$\forall A (wren_{h1} \land A = \text{wraddrFunc} \rightarrow \forall B (\text{range}_{[35,0]}(B) \rightarrow (\text{imem}'(A, B) \leftrightarrow \text{iwrite}(B)))))$$

Automated reasoning — verification of correct behaviour.
Hardware verification

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![RTL and SCH diagrams](image)

Behaviour of such circuits can be represented as **first-order formulas**:

\[ \forall A(wren_{h1} \land A = wraddrFunc \rightarrow \forall B(range_{[35,0]}(B) \rightarrow (imem'(A, B) \leftrightarrow iwrite(B)))) \].

**Automated reasoning** — verification of correct behaviour.
Applications of Automated Reasoning

Ensuring correct functioning of complex systems
Software + hardware verification
seL4 Microkernel verified correct, NiCTA, 2009
Major companies intensively using AR tools:
Intel, Microsoft, NASA, Mercedes, Toyota, Airbus

Security: protocol verification

Combinatorial reasoning: constraint problems
Professional sports scheduling (Barcelologic)
Planning
Optimisation

AR proving open mathematical problems
Solution of Robbins Algebra Problem, NYT, 1996
Erdős discrepancy conjecture, 2014.
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 Department:**
  - 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.
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What is covered in the course:

**Basics:** propositional/first-order logic: syntax, semantics, …

**Efficient automated reasoning:** backjumping, lemma learning; first-order resolution, redundancy elimination,…

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

**Questions? please email:**

Konstantin Korovin (room 2.40) Renate Schmidt (room 2.42)
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