
DTU

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Proof Assistants and Related Tools

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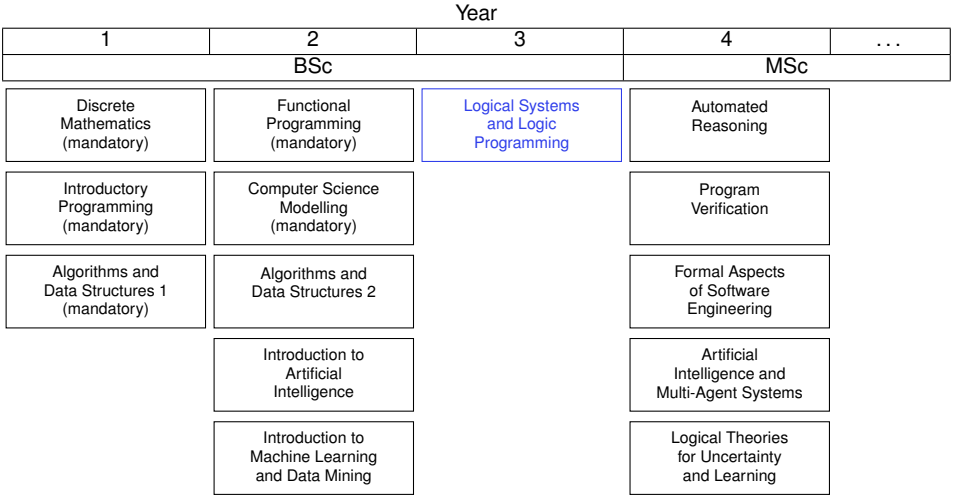
Introduction

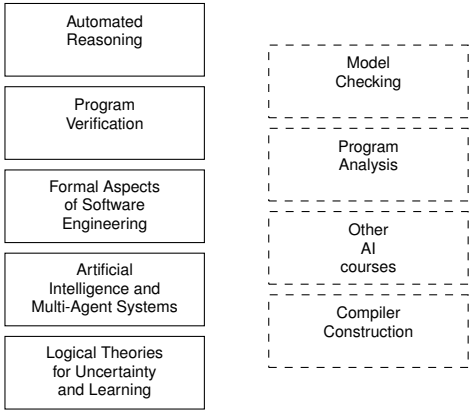
- *Technical* University of Denmark – undergraduate software *engineering* students
- Undergraduate logic course: Logical Systems and Logic Programming (80+ students)
- Graduate logic course: Automated Reasoning (40+ students)
- Undergraduate course leads into many other courses and potentially a thesis project
- 50% lectures and 50% supervised exercise sessions, plus homework assignments
- Danish custom: almost all students pursue a MSc degree

The surrounding curriculum



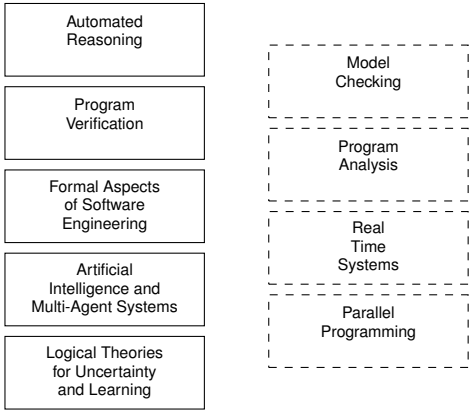
Axioms and inference rules

- Why pick one over the other?
- Notation is widely used
- Special case: type systems



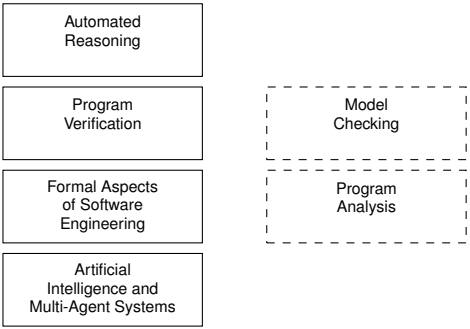
Extensions to a logic

- In practice, first-order logic is not enough
- Examples:
  - Modal Logic
  - Separation Logic
  - Epistemic Logic
  - Hoare Logic
  - Higher-order logic



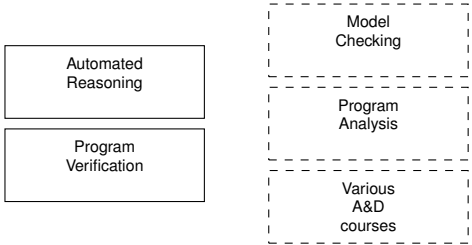
Soundness and completeness

- Basic understanding is enough
- Sound approximations
- Proof systems



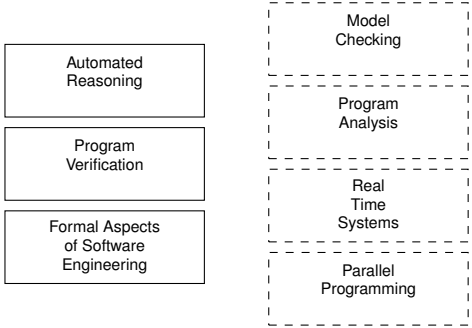
Decidability

- Basic understanding is enough
- Techniques for proving termination
- Only practical examples are useful!



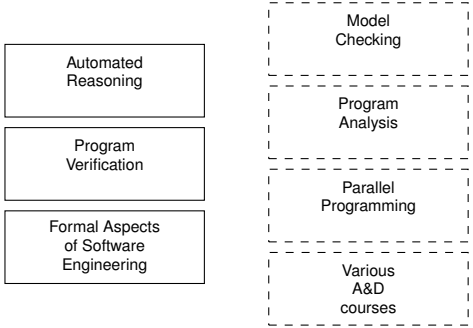
Writing formal specifications

- Verification tools need formal specifications
- Connection to the real world
- Approximations and models



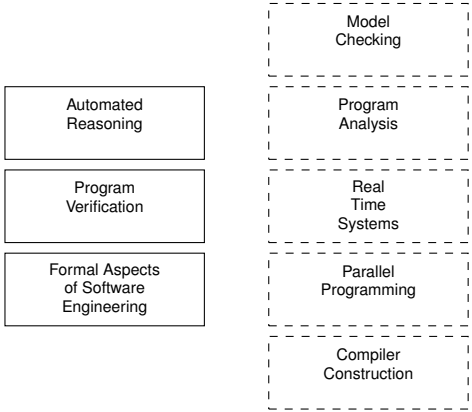
Writing formal proofs

- Needed for all proofs when they become difficult
- Many techniques to explore and practice
- Focus should be on strategies, not particular proofs!



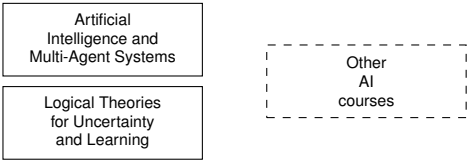
Proof algorithms

- How do automated theorem provers work?
- The foundation of formal analysis tools
- Special case: type checkers



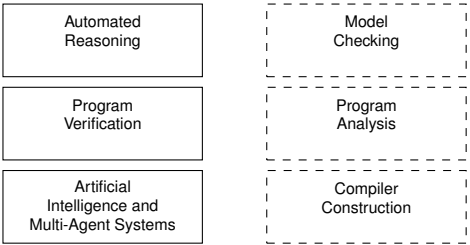
Representing knowledge

- Foundation of artificial intelligence
- Logic programming
- Databases



Implementations

- Theory is not enough
- Complexity of binders, substitution, etc. is often swept under the rug
- Often much harder than expected – see e.g. the POPLmark challenge



Topics I did not mention

- “Advanced” set theory
  - Belongs in a math course
- Recursion theory
  - Non-computable functions are not useful for computer science undergraduates
  - Complexity theory belongs in courses on algorithms and data structures
- Non-finite model theory
  - Quantifier elimination and decidability belongs in a course on automated reasoning
- Non-structural proof theory
  - Proof-theoretic semantics are interesting, but belongs in a specialized course

Summary of topics

- Axioms and inference rules
- Extensions to a logic
- Soundness and completeness
- Decidability
- Writing formal specifications
- Writing formal proofs
- Proof algorithms
- Representing knowledge
- Implementations

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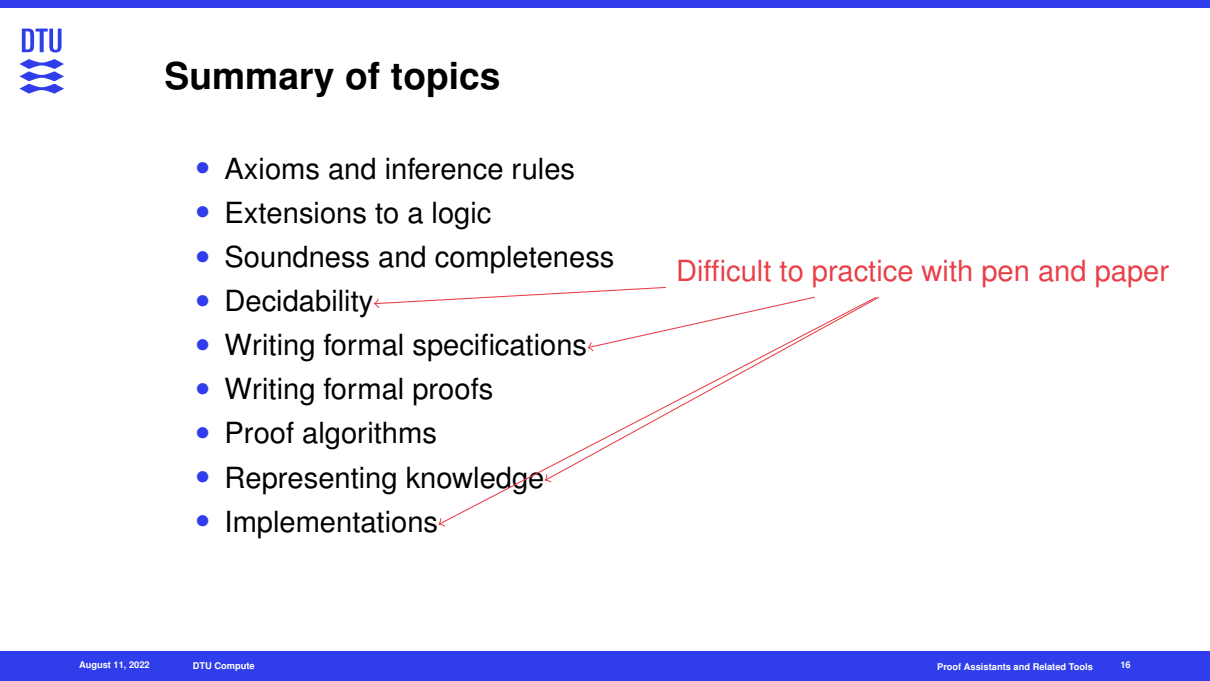

Proof assistants

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- All the things!
  - Axioms and inference rules
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- And more:
  - Confidence when experimenting
  - Instant feedback on definitions and proofs
  - Implemented examples of proof algorithms and formal proofs