Logic: Theory and Applications

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Plan

Today:

- What is a Logic?
- Topics
- Practicalities

What Is Logic?

An Extremely Brief History of Logic

Broadly speaking

Logic is the theory of formal reasoning.

4 BC:	Aristoteles develops the syllogistic logic.
	⋮
19th c.:	Classical logic is born.
20th c.:	The foundations of classical logic are developed.
	⋮

Logics

In a strict sense

A logic consists of a formal language, a semantics and a notion of logical consequence.

When learning a new logic we are interested in:

- Motivation.
- Syntax and semantics.
- Model theory and proof systems.
- Soundness and completeness.
- Decidability.
- ....

Topics

Modal Logics

1. Classical modal logics. (K,S4, ...)
   → "If I talk to my tutor, then it is possible that I get a good grade."
2. Linear and branching time logics. (LTL,CTL)
   → "If I talk to my tutor, then eventually I will get a good grade".
3. Probabilistic temporal logic. (PCTL)
   → "If I talk to my tutor, then the probability of eventually getting a good grade is 94%".
4. Modal μ-calculus.
   → fixedpoint operators!

Brave Old New World

5. Hoare logic.
   → Show correctness of programs.

6. Intuitionistic propositional logic.
   → What happens when the law of excluded midle is rejected?

7. Paraconsistent logics (LP, Dunn-Belnap)
   → reasoning in the presence of contradictions.

A Bit More Concrete

The Satisfiability Problem

Problem

Given an arbitrary formula F of propositional logic, decide whether there is a model for F.

- The first problem shown to be NP-complete.
- It is used as a stepping stone in many NP-completeness proofs.

8. Modern SAT solving.
   Goal: Study modern solvers and compare them to classical ones.
9. SAT preprocessing.
   Goal: Study techniques that simplify formulas before passing them to solvers.
10. Generating hard instances.
    Goal: Study techniques to generate formulas that are typically hard to solve.
11. Renamable Horn and generalized Horn.
    Goal: Study certain classes of formulas that can be solved efficiently.
12. CryptoSAT.
    Goal: Study how SAT solvers are used in cryptanalysis.

Misc

13. Post's Functional Completeness Theorem.

    Is the set of connectives $\{\rightarrow, \bot\}$ functional complete?

    Goal: Study (the **proof** of) Post's theorem and its influence in logic and computer science.

14. Elementary Equivalence and Ehrenfeucht-Fraisse Games.

    Games played by two players: Spoiler and Duplicator.
    Thm: Two structures are *elementary equivalent* iff Duplicator has a winning strategy for every k-depth game.

    Goal: Study how games can be used in logic.

15. Tableau calculi.

    Goal: Study a class of proof methods that is available for a variety of logics.

Practicalities

You Are Expected To

Give a talk

- $\approx$ 45 minutes + $\approx$ 15 minutes for discussion.
- English or German.
- Include an interactive element.

Write a report

- Extended version of your talk.
- English or German.
- **Tip:** Use LaTeX.

Attend the seminar sessions

- Mandatory.

  Need to skip a session? $\Rightarrow$ email pedro.nora@uni-due.de

- Contribute to discussions.

Next Steps

You will be:

1. enrolled in the Moodle course.
   - annoucements.
   - forum.
   - list of topics and references.
2. assigned a topic.
3. **assigned a tutor**.
4. assigned a presentation date via Moodle.
5. doing your own research and having fun!

Selection of Topics

Important!

- Rank your **three** preferred topics and send the list to pedro.nora@uni-due.de **until Wednesday**.
- Indicate whether you are a bachelor's student.
- indicate whether you prefer tutoring in English, German, or either.

- Ideally: each topic is assigned to no more than one student.
- **Goal**: Maximize overall group preferences.
- The slides for this talk will be available on Moodle.

Evaluation and Generative AI

Evaluation

- The talk will place you within a grade range.
- The final grade will be determined after evaluating the report.
- Plagiarism can lead to a **failing grade**.

Generative AI

- The use of generative AI for **support** is not prohibited.
- Discuss the use of any generative AI with your **tutor** in advance.
- AI-assisted content must be identified as such.

Do You Want a Good Grade?

Do You Want a Good Grade?

Talk to your tutor!