Logic: Theory and Applications

R. Adamy, S. Gurke, B. König, K. Messing, **P. Nora** and F. Wittbold

October 12, 2026

Universität Duisburg-Essen
pedro.nora@uni-due.de

Plan

Today:

- What is 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 ★
   - ▷ Modern solvers and their comparison with classical ones.
9. SAT Preprocessing ★
   - ▷ Techniques that simplify formulas before passing them to solvers.
10. Generating Hard Instances
    - ▷ Techniques to generate formulas that are typically hard to solve.
11. Renamable Horn and Generalized Horn
    - ▷ Classes of formulas that can be solved efficiently.
12. CryptoSAT ★★★
    - ▷ SAT solvers in cryptanalysis.

Misc

13. Post's Functional Completeness Theorem

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

    ▷ Post's theorem (**proof**) 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.

    ▷ Games in logic.

15. Tableau Calculi ★

    ▷ Class of proof methods that is available for a variety of logics.

Summary

- Topics on specific logics (1-7) have a higher entry barrier **but** preparing a talk on them is relatively easy.
- The other topics, except 12, have a lower entry barrier **but** may require more in-depth study.
- Topics marked with ★ are **reserved** for bachelor's students.
- Topics marked with ★★★ are **recommended** for master's students.

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 ($\approx$ 5 - 10 pages).
- 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

Important!

- Register on Moodle until **October 20**.
- Register at the examination office from **November 9** to **November 20**.

You will be:

1. enrolled in the Moodle course;
   - ▷ annoucements, forum, list of topics and references.
2. assigned a topic and a **tutor**;
3. assigned a presentation date via Moodle;
   - ▷ first session: November 16.
4. doing your own research and having fun!

Selection of Topics

Important!

- Rank your top **five** topics and email your list to pedro.nora@uni-due.de **until Wednesday**.
  - ★: reserved for bachelor's students.
  - ★★★: recommend for master's students.
- 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 the website.

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!