Part I

Course Technicalities
General Information

- Main source of information is the website
  https://liacs.leidenuniv.nl/~basoldh/education/logic2020.html
- Also linked in studiegids. Search for 4031ILOGI
- If you have questions that are not answered during the lecture, on the website or on the exercise sheet, then you always send an email to
  itl20@liacs.leidenuniv.nl
  (itl = introduction to logic)
- We will use Blackboard for assignments, grades and announcements
  - Please enrol during the break
  - Search for course ID 4031ILOGI-1920FWN
Schedule

- Details on website
- 13 weeks
- 12 lectures with content and exercise classes
- 13th lecture will (most likely) be given by prof. Holger Hoos
  - Monday 25 May, 14:15
  - Content: Implementing and Comparing SAT-solvers
  - Not part of exam, but interesting! 😊
- 13th exercise class will be last lecture
  - Monday 25 May, 16:00
  - Will be in Sitterzaal! (here)
  - Summary and question session
Lectures

- Monday block 6 and 7 (14:15), but you know that since you’re here!
- Topic: Introduction to formal logic and how it fits to computer science
- Goals:
  - Give you an idea of what logic is
  - Enable you to study logic autonomously
- Lecture style
  - On blackboard (yes, old-fashioned!)
  - This means that there are no slides etc.
  - If you miss a lecture, ask your friendly colleagues for their notes
  - I encourage you to participate and ask questions during the lectures!
- A full list of reading material is given on the website
  - Open Logic Project (openlogicproject.org)
  - Johan van Benthem et al. Logica voor informatica
Exercise Classes and Homework

- Exercise class in Snellius 401, 402, 403, 405 and 412
- Monday blocks after the lecture (16:15)
- I will distribute groups on Blackboard during the break (Please enrol!)
- Weekly assignments
  - Can be worked on during the exercise class
  - Class is supervised
  - Use the chance to work there and ask questions!
  - Each assignment consists of exercises for practising and homework
- Homework
  - The homework is mandatory …
  - …in the sense that it makes 30% of the final grade
  - Deadline is always Friday Afternoon
  - Submission via Blackboard
  - Only pdfs generated with \LaTeX, \Xi{LaTeX} etc. are accepted
  - If you don’t have a computer with working \LaTeX, use Overleaf (https://www.overleaf.com/)
  - Detailed and binding instructions are on exercise sheets and website
## Exercise Class Rooms

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Room</th>
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<tbody>
<tr>
<td>Lau Bannenberg</td>
<td>SN 407-409</td>
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<tr>
<td>Tomke Meyer</td>
<td>SN 402</td>
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<tr>
<td>Tim Poot</td>
<td>SN 403</td>
</tr>
<tr>
<td>Nick Radunović</td>
<td>SN 405</td>
</tr>
<tr>
<td>Levi Vos</td>
<td>SN 412</td>
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</table>
Final exam on Monday 15 June, 14:15 retake on Tuesday 07 July, 14:15
You can bring two hand-written A4 cheat sheets (double-sided)
I will distribute an sample exam before the question session on 25 May
Exam should be a walk in the park, if you
  attend the lectures,
  do the weekly assignments,
  hand in weekly the homework, and
  practise, if necessary, with the sample exam.
Part II

Introduction
What is Logic and Why Should You Care?
I would like to argue [...] that without a system of formal constraints there are no creative acts; specifically, in the absence of intrinsic and restrictive properties of mind, there can be only ‘shaping of behavior’ but no creative acts of self-perfection.

Noam Chomsky [1]

Chomsky Hierarchy

- Modern understanding of formal languages
- Essential to CS (compilers, text search, etc.)
What is Logic?

**Study of arguments and the form they may take**
- Formal languages to express facts and propositions
- Formal proofs to make valid deductions (redeneringen)
- Semantics (betekenis/semantiek) to study where meaning comes from

**Applications**
- Formalise mathematical proofs
- Formalise scientific and philosophical arguments
- Formalise models of computation and correctness of software
Computing would not exist without logic!

Yes, this is from a different century!

When a man *reasoneth*, he does nothing else but *conceive a sum total* [...] For as arithmeticians teach to add and subtract in numbers; [...] the logicians teach the same in consequences of words; — Leviathan, 1651.

Thomas Hobbes [2]
Logic in Computer Science

- Computers do nothing but executing logical operations (very quickly!)
- Semantics of programming languages
- Program correctness
- Automatic deduction
- Computer-verified proofs
### Ex Nihilo – Creation from Nothing

\[
0 = 0 + 0 + 0 + \cdots \\
= (1 - 1) + (1 - 1) + (1 - 1) + \cdots \\
= (1 + (-1)) + (1 + (-1)) + (1 + (-1)) + \cdots \\
= 1 + ((-1) + 1) + ((-1) + 1) + \cdots \\
= 1 + 0 + 0 + \cdots \\
= 1
\]
What Went Wrong?

- We did not adhere to a rigorous definition of convergence
- Without making assumptions and deduction explicit, we can prove anything

Corollary (of Ex Nihilo)

“I will not drink this night!”

Proof.

By induction, using that one beer is no beer 😞
Content of this Course

- Propositional logic — Expressing simple logical relations
- Predicate logic — Expressing facts about data
- Proof systems – Formal deductions
- The essentials of studying logic: syntax, semantics, soundness, completeness, decidability, expressivity
- Focus on computing and constructivism
- Practical relevance of formal logic: SAT/SMT-solving and logic programming
- Limits of logic and reasoning: Gödel’s incompleteness theorem
A Bit of Logic History
As the Early Days...

- Aristotle (384 – 322 BC)
- Euclid (ca. 360 BC)
- Middle Ages

Typical Argument

All human are mortal
Socrates is a human

Socrates is mortal
# The Birth of Formal Logic

<table>
<thead>
<tr>
<th>Gottfried Wilhelm Leibniz (1646 – 1716)</th>
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<tbody>
<tr>
<td>▶ Display relations of objects and concepts in formal language</td>
</tr>
<tr>
<td>▶ Universal language for mathematics (Characteristica universalis)</td>
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<tr>
<td>▶ Algorithmic deduction (Calculus ratiocinator)</td>
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<table>
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<tr>
<th>Algebraic Logic</th>
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<tr>
<td>Deductions as calculations.</td>
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<tr>
<td>▶ <strong>George Boole</strong> (1815 – 1864)</td>
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<td>▶ Augustus de Morgan (1806 – 1871)</td>
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<td>▶ Charles Sanders Peirce (1839 – 1914)</td>
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<td>▶ Ernst Schröder (1841 – 1902)</td>
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## Logicism

All mathematics can be reduced to logic. We only uncover the truth.

- **Gottlob Frege** (1848 – 1925)
- **Betrand Russell** (1872 – 1970)
- **Alfred North Whitehead** (1861 – 1925)
- **Guiseppe Peano** (1858 – 1932)


## Intuitionism

Mathematics only exists as mental activity, not independently.

- **Leopold Kronecker** (1823 – 1891)
- **Luitzen Egbertus Jan Brouwer** (1881 – 1966)
- **Arend Heyting** (1898 – 1980)
- **Anne Sjerpe Troelstra** (1939 – 2019)
## Formalism

All of logic and mathematics is a consequence of string manipulations.

- **David Hilbert** (1862 – 1943)
- **Gerhard Gentzen** (1909 – 1945)
- **Haskell B. Curry** (1900 – 1982)

## Hilbert’s programme

Axiomatic system to formalise all mathematics and prove this system correct.

- **Kurt Gödel** (1906 – 1978) showed that this is impossible
What does this have to do with computation?

- Ada Lovelace (1815 – 1852): Potential of Babbage’s analytical engine
- Thoralf Skolem (1887 – 1963): Primitive recursion
- Alonzo Church (1903 – 1995): $\lambda$-calculus
- **Alan Turing** (1912 – 1954): Turing machine
Part III

Appendix

