Artificial Intelligence 1
Winter Semester 2024/25

– Lecture Notes –
Admin & Overview

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Chapter 1
Preliminaries

1.1 Administrative Ground Rules

Prerequisites for AI-1

- **Content Prerequisites:** The mandatory courses in CS@FAU; Sem. 1-4, in particular:
  - Course "Algorithmen und Datenstrukturen". (Algorithms & Data Structures)
  - Course "Grundlagen der Logik in der Informatik" (GLOIN). (Logic in CS)
  - Course "Berechenbarkeit und Formale Sprachen". (Theoretical CS)

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- **Skillset Prerequisite:** Coping with mathematical formulation of the structures
  - Mathematics is the language of science (in particular computer science)
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- **Intuition:** (take them with a kilo of salt)
  - This is what I assume you know! (I have to assume something)
  - In most cases, the dependency on these is partial and "in spirit".
  - If you have not taken these (or do not remember), read up on them as needed!

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  - In most cases, the dependency on these is partial and "in spirit".
  - If you have not taken these (or do not remember), read up on them as needed!
- **Real Prerequisites:** Motivation, interest, curiosity, hard work. (AI-1 is non-trivial)
- You can do this course if you want! (and I hope you are successful)

Assessment, Grades

- **Overall (Module) Grade:**
  - Grade via the exam (Klausur) $\rightsquigarrow$ 100% of the grade.
  - Up to 10% bonus on-top for an exam with $\geq$ 50% points. ($<$ 50% $\rightsquigarrow$ no bonus)
  - Bonus points $\widehat{=}$ percentage sum of the best 10 prepquizzes divided by 100.

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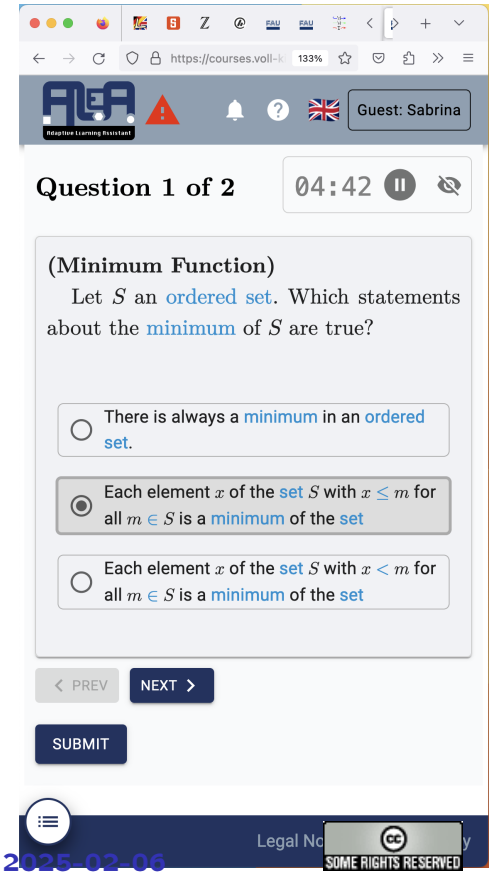
- **Exam:** 90 minutes exam conducted in presence on paper! ($\sim$ April 1. 2025)
- **Retake Exam:** 90 min exam six months later. ($\sim$ October 1. 2025)
- ⚠ Register for exams in `https://campo.fau.de`. (there is a deadine!)
- **Note:** You can de-register from an exam on `https://campo.fau.de` up to three working days before exam. (do not miss that if you are not prepared)

Preparedness Quizzes

- **PrepQuizzes:** Every tuesday 16:15 we start the lecture with a 10 min online quiz – the PrepQuiz – about the material from the previous week.(starts in week 2)
- **Motivations:** We do this to
  - keep you prepared and working continuously. (primary)
  - update the ALeA learner model (fringe benefit)
- The prepquiz will be given in the ALeA system

- `https://courses.voll-ki.fau.de/quiz-dash/ai-1`
- You have to be logged into ALeA! (via FAU IDM)
- You can take the prepquiz on your laptop or phone, . . .
- . . . in the lecture or at home . . .
- . . . via WLAN or 4G Network. (do not overload)
- Prepquizzes will only be available 16:15-16:25!



This Thursday: Pretest

- ⚠ This thursday we will try out the prepquiz infrastructure with a pretest!
  - **Presence**: bring your laptop or cellphone.
  - **Online**: you can and should take the pretest as well.
  - Have a recent firefox or chrome (chrome: younger than March 2023)
  - Make sure that you are logged into ALeA (via FAU IDM; see below)
- **Definition 1.1.** A pretest is an assessment for evaluating the preparedness of learners for further studies.
- **Concretely:** This pretest
  - establishes a baseline for the competency expectations in AI-1 and
  - tests the ALeA quiz infrastructure for the prepquizzes.
- Participation in the pretest is optional; it will not influence grades in any way.
- The pretest covers the prerequisites of AI-1 and some of the material that may have been covered in other courses.
- The test will be also used to refine the ALeA learner model, which may make learning experience in ALeA better. (see below)

Special Admin Conditions

- Some degree programs do not "import" the course Artificial Intelligence 1, and thus you may not be able to register for the exam via `https://campo.fau.de`.
  - Just send me an e-mail and come to the exam, (we do the necessary admin)
  - Tell your program coordinator about AI-1/2 so that they remedy this situation
- In "Wirtschafts-Informatik" you can only take AI-1 and AI-2 together in the "Wahlpflichtbereich".
  - ECTS credits need to be divisible by five $\rightsquigarrow 7.5 + 7.5 = 15$.

1.2 Getting Most out of AI-1

AI-1 Homework Assignments

- **Goal:** Homework assignments reinforce what was taught in lectures.
- **Homework Assignments:** Small individual problem/programming/proof task
  - but take time to solve (at least read them directly $\rightsquigarrow$ questions)
- **Didactic Intuition:** Homework assignments give you material to test your understanding and show you how to apply it.
- ⚠ Homeworks give no points, but without trying you are unlikely to pass the exam.

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- **Didactic Intuition:** Homework assignments give you material to test your understanding and show you how to apply it.
-  Homeworks give no points, but without trying you are unlikely to pass the exam.
- Homeworks will be mainly peer-graded in the ALEA system.
- **Didactic Motivation:** Through peer grading students are able to see mistakes in their thinking and can correct any problems in future assignments. By grading assignments, students may learn how to complete assignments more accurately and how to improve their future results. (not just us being lazy)

AI-1 Homework Assignments – Howto

- **Homework Workflow:** in ALEA (see below)
  - Homework assignments will be published on thursdays: see `https://courses.voll-ki.fau.de/hw/ai-1`
  - Submission of solutions via the ALEA system in the week after
  - Peer grading/feedback (and master solutions) via answer classes.
- **Quality Control:** TAs and instructors will monitor and supervise peer grading.

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- **Quality Control:** TAs and instructors will monitor and supervise peer grading.
- **Experiment:** Can we motivate enough of you to make peer assessment self-sustaining?
  - I am appealing to your sense of community responsibility here . . .
  - You should only expect other's to grade your submission if you grade their's (cf. Kant's "Moral Imperative")
  - **Make no mistake**: The grader usually learns at least as much as the gradee.

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- **Homework/Tutorial Discipline:**
  - Start early! (many assignments need more than one evening's work)
  - Don't start by sitting at a blank screen (talking & study groups help)
  - Humans will be trying to understand the text/code/math when grading it.
  - Go to the tutorials, discuss with your TA! (they are there for you!)

Tutorials for Artificial Intelligence 1

- **Approach:** Weekly tutorials and homework assignments (first one in week two)
- **Goal 1:** Reinforce what was taught in the lectures. (you need practice)
- **Goal 2:** Allow you to ask any question you have in a protected environment.

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- **Approach:** Weekly tutorials and homework assignments (first one in week two)
- **Goal 1:** Reinforce what was taught in the lectures. (you need practice)
- **Goal 2:** Allow you to ask any question you have in a protected environment.
- **Instructor/Lead TA:** Florian Rabe (KWARC Postdoc)
  - Room: 11.137 @ Händler building, `florian.rabe@fau.de`
- **Tutorials:** One each taught by Florian Rabe (lead); Yasmeen Shawat, Hatem Mousa, Xinyuan Tu, and Florian Guthmann.
- **Life-saving Advice:** Go to your tutorial, and prepare for it by having looked at the slides and the homework assignments!

Collaboration

- **Definition 2.1.** Collaboration (or cooperation) is the process of groups of agents acting together for common, mutual benefit, as opposed to acting in competition for selfish benefit. In a collaboration, every agent contributes to the common goal and benefits from the contributions of others.
- In learning situations, the benefit is "better learning".
- **Observation:** In collaborative learning, the overall result can be significantly better than in competitive learning.
- **Good Practice:** Form study groups. (long- or short-term)
  1. ⚠ those learners who work most, learn most!
  2. ⚠ freeloaders – individuals who only watch – learn very little!
- It is OK to collaborate on homework assignments in AI-1! (no bonus points)
- Choose your study group well! (We will (eventually) help via ALeA)

Do I need to attend the AI-1 Lectures

- Attendance is not mandatory for the AI-1 course. (official version)
- **Note:** There are two ways of learning: (both are OK, your mileage may vary)
  - Approach B: Read a book/papers (here: lecture notes)
  - Approach I: come to the lectures, be involved, interrupt the instructor whenever you have a question.

  The only advantage of I over B is that books/papers do not answer questions
- Approach S: come to the lectures and sleep does not work!
- The closer you get to research, the more we need to discuss!

1.3 Learning Resources for AI-1

Textbook, Handouts and Information, Forums, Videos

- **Textbook:** *Russel/Norvig: Artificial Intelligence, A modern Approach* [RN09].
  - basically "broad but somewhat shallow"
  - great to get intuitions on the basics of AI

  Make sure that you read the edition ≥ 3 $\rightsquigarrow$ vastly improved over ≤ 2.

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  - more detailed than [RN09] in some areas
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- **Course Videos:** AI-1 will be streamed/recorded at `https://fau.tv/course/id/4047`
  - **Organized**: Video course nuggets are available at `https://fau.tv/course/id/1690` (short; organized by topic)
  - **Backup**: The lectures from WS 2016/17 to SS 2018 have been recorded (in English and German), see `https://www.fau.tv/search/term.html?q=Kohlhase`

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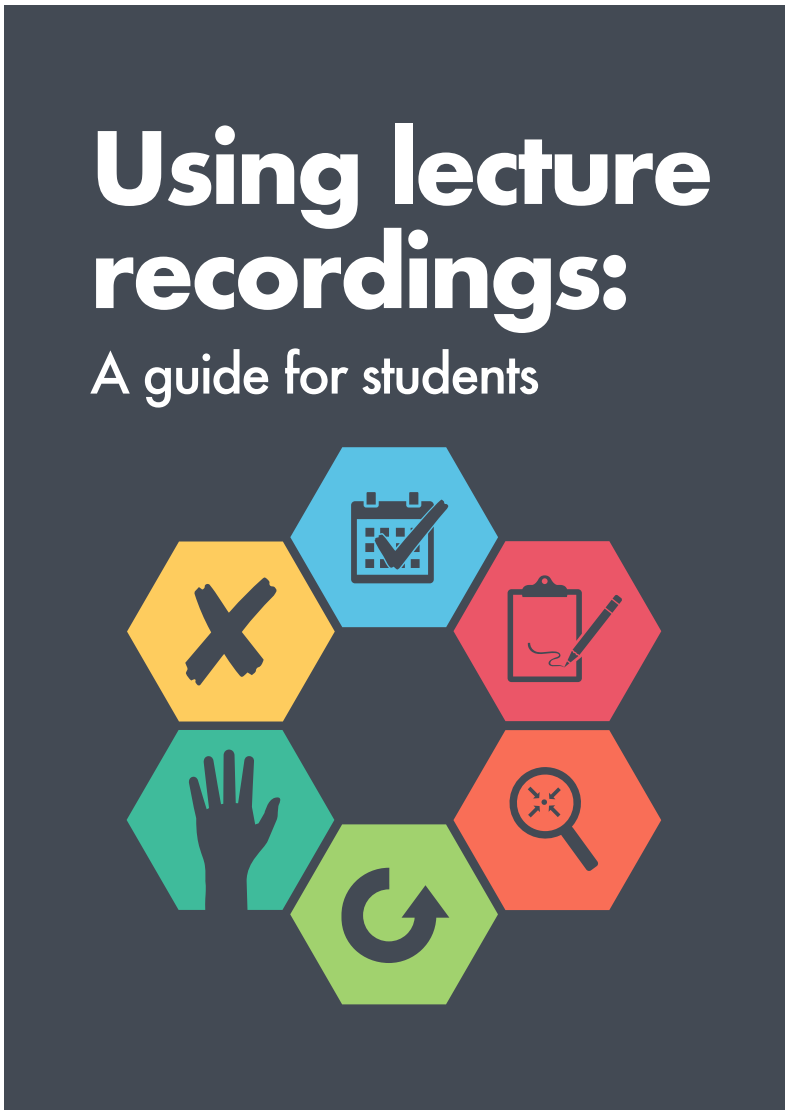
- **Do not let the videos mislead you:** Coming to class is highly correlated with passing the exam!
- **StudOn Forum:** `https://www.studon.fau.de/crs5832535.html` for
  - announcements, homeworks (my view on the forum)
  - questions, discussion among your fellow students (your forum too, use it!)

Practical recommendations on Lecture Videos

- **Excellent Guide:** [Nor+18a] (German version at [Nor+18b])



NOT a Resource for : LLMs – AI-based tools like ChatGPT

- **Definition 3.1.** A large language model (LLM) is a computational model capable of language generation or other natural language processing tasks.
- **Example 3.2.** OpenAI's GPT, Google's Bard, and Meta's Llama.

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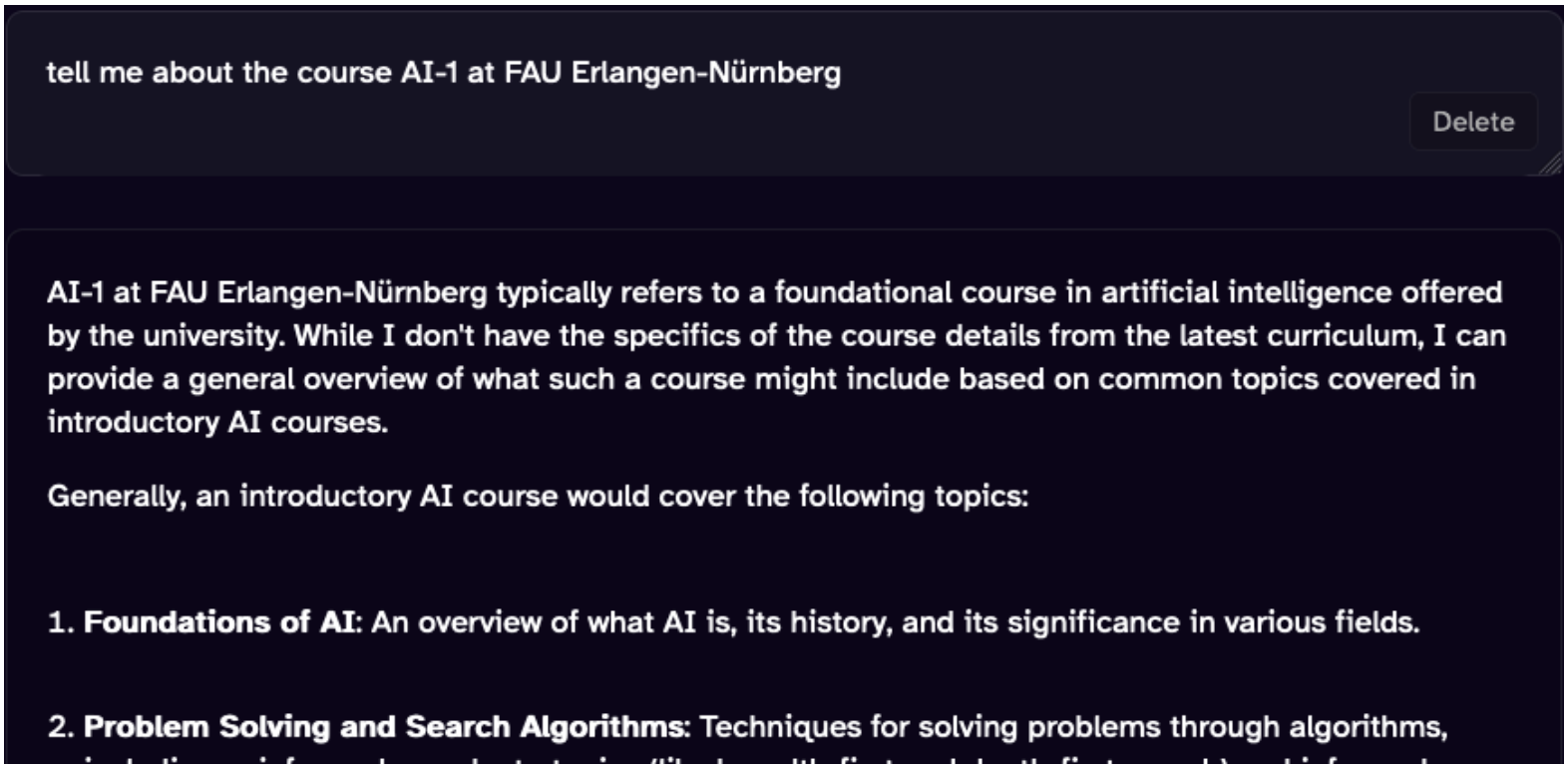
- **Definition 3.6.** A large language model (LLM) is a computational model capable of language generation or other natural language processing tasks.
- **Example 3.7.** OpenAI's GPT, Google's Bard, and Meta's Llama.
- **Definition 3.8.** A chatbot is a software application or web interface that is designed to mimic human conversation through text or voice interactions. Modern chatbots are usually based on LLMs.
- **Example 3.9 (ChatGPT talks about AI-1).** (but remains vague)



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- **Definition 3.11.** A large language model (LLM) is a computational model capable of language generation or other natural language processing tasks.
- **Example 3.12.** OpenAI's GPT, Google's Bard, and Meta's Llama.
- **Definition 3.13.** A chatbot is a software application or web interface that is designed to mimic human conversation through text or voice interactions. Modern chatbots are usually based on LLMs.
- **Example 3.14 (ChatGPT talks about AI-1).** (but remains vague)
- **Note:** LLM-based chatbots invent *every word*! (suprpisingly often correct)
- **Example 3.15 (In the AI-1 exam).** ChatGPT scores ca. 50% of the points.
  - ChatGPT can almost pass the exam ... (We could award it a Master's degree)
  - But can you? (the AI-1 exams will be in person on paper)

  You will only pass the exam, if you can do AI-1 yourself!

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- **Definition 3.16.** A large language model (LLM) is a computational model capable of language generation or other natural language processing tasks.
- **Example 3.17.** OpenAI's GPT, Google's Bard, and Meta's Llama.
- **Definition 3.18.** A chatbot is a software application or web interface that is designed to mimic human conversation through text or voice interactions. Modern chatbots are usually based on LLMs.
- **Example 3.19 (ChatGPT talks about AI-1).** (but remains vague)
- **Note:** LLM-based chatbots invent *every word*! (suprpisingly often correct)
- **Example 3.20 (In the AI-1 exam).** ChatGPT scores ca. 50% of the points.
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  - But can you? (the AI-1 exams will be in person on paper)

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- **Intuition:** AI tools like GhatGPT, CoPilot, etc. (see also [She24])
  - can help you solve problems, (valuable tools in production situations)
  - hinders learning if used for homeworks/quizzes, etc. (like driving instead of jogging)

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- **Definition 3.21.** A large language model (LLM) is a computational model capable of language generation or other natural language processing tasks.
- **Example 3.22.** OpenAI's GPT, Google's Bard, and Meta's Llama.
- **Definition 3.23.** A chatbot is a software application or web interface that is designed to mimic human conversation through text or voice interactions. Modern chatbots are usually based on LLMs.
- **Example 3.24 (ChatGPT talks about AI-1).** (but remains vague)
- **Note:** LLM-based chatbots invent *every word*! (suprpisingly often correct)
- **Example 3.25 (In the AI-1 exam).** ChatGPT scores ca. 50% of the points.
  - ChatGPT can almost pass the exam ... (We could award it a Master's degree)
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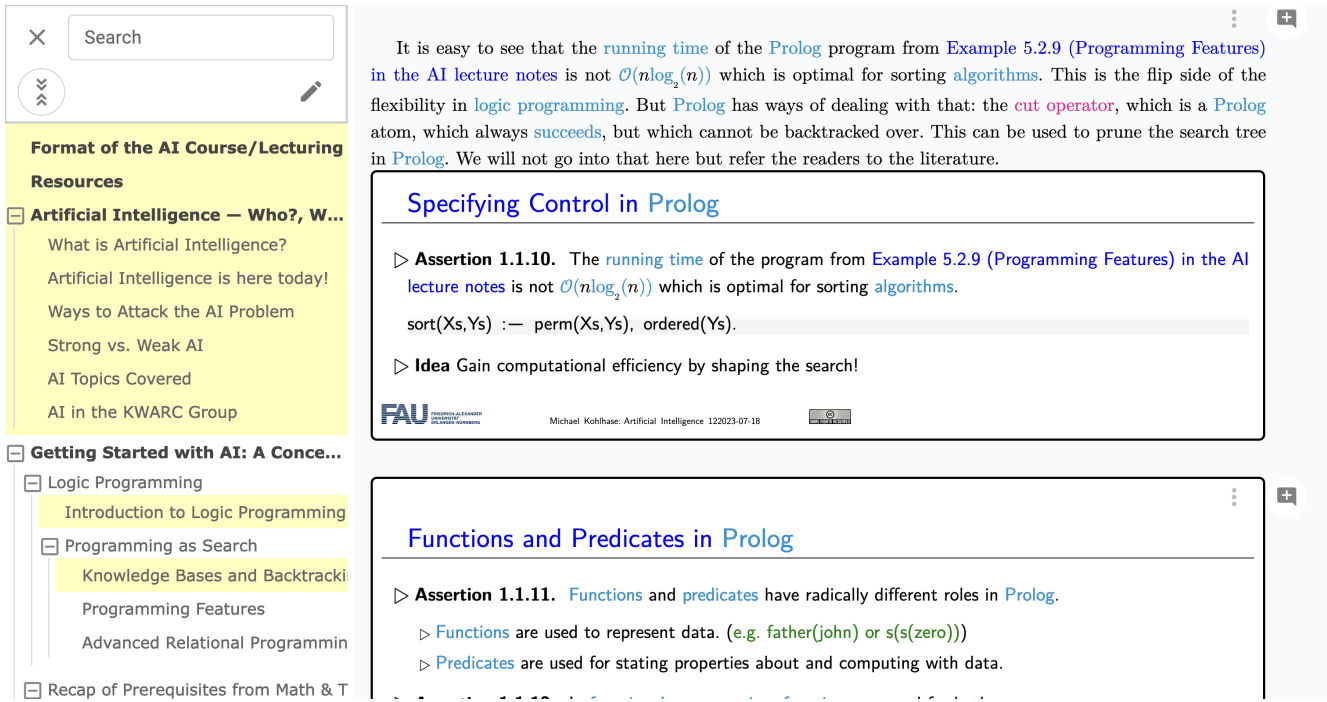
  - can help you solve problems, (valuable tools in production situations)
  - hinders learning if used for homeworks/quizzes, etc. (like driving instead of jogging)
- **What (not) to do:** (to get most of the brave new AI-supported world)
  - try out these tools to get a first-hand intuition what they can/cannot do
  - challenge yourself while learning so that you can also do it (mind over matter!)

1.4 AI-Supported Learning

ALEA: Adaptive Learning Assistant

- **Idea:** Use AI methods to help teach/learn AI (AI4AI)
- **Concretely:** Provide HTML versions of the AI-1 slides/lecture notes and embed learning support services into them. (for pre/postparation of lectures)
- **Definition 4.1.** Call a document active, iff it is interactive and adapts to specific information needs of the readers. (lecture notes on steroids)
- **Intuition:** ALEA serves active course materials. (PDF mostly inactive)
- **Goal:** Make ALEA more like a instructor + study group than like a book!
- **Example 4.2 (Course Notes).** $\widehat{=}$ Slides + Comments



$\rightsquigarrow$ yellow parts in table of contents (left) already covered in lectures.

VoLL-KI Portal at https://courses.voll-ki.fau.de

- **Portal for ALeA Courses:** https://courses.voll-ki.fau.de

- **AI-1 in ALeA:** https://courses.voll-ki.fau.de/course-home/ai-1
  - All details for the course.
  - recorded syllabus (keep track of material covered in course)
  - syllabus of the last semesters (for over/preview)
- **ALeA Status:** The ALeA system is deployed at FAU for over 1000 students taking eight courses
  - (some) students use the system actively (our logs tell us)
  - reviews are mostly positive/enthusiastic (error reports pour in)

Learning Support Services in ALeA

- **Idea:** Embed learning support services into active course materials.

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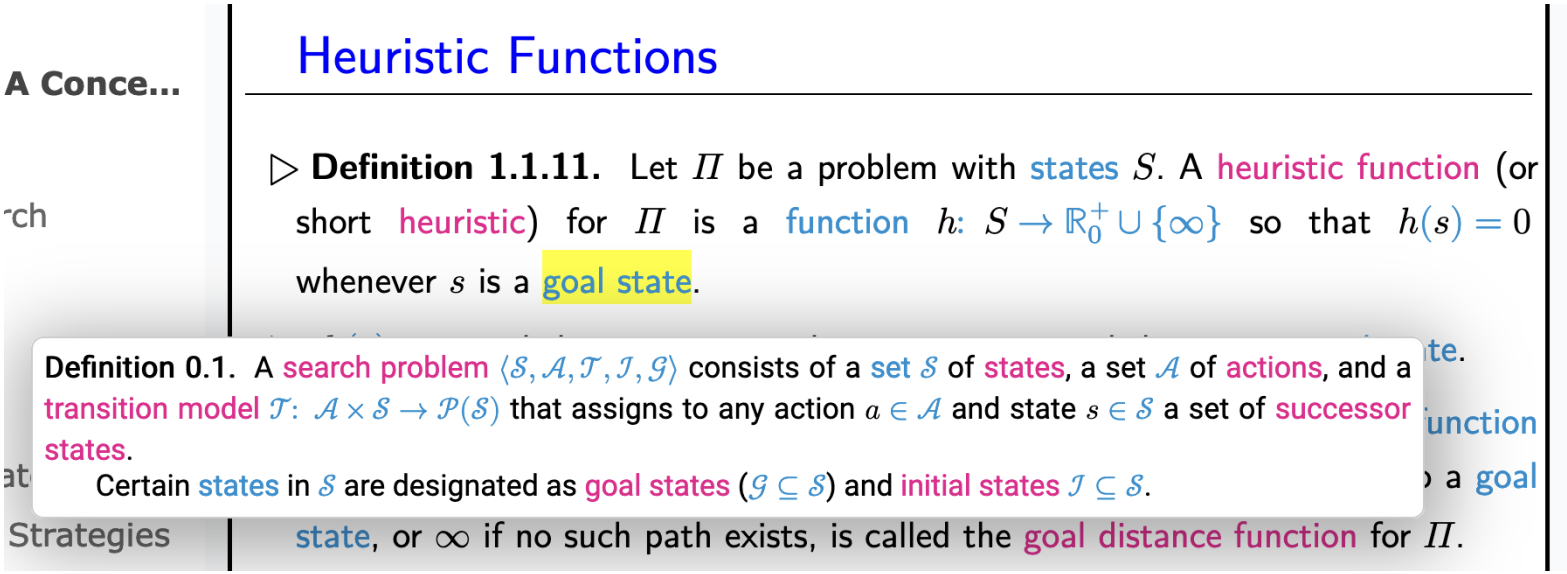
- **Example 4.6 (Definition on Hover).** Hovering on a (cyan) term reference reminds us of its definition. (even works recursively)



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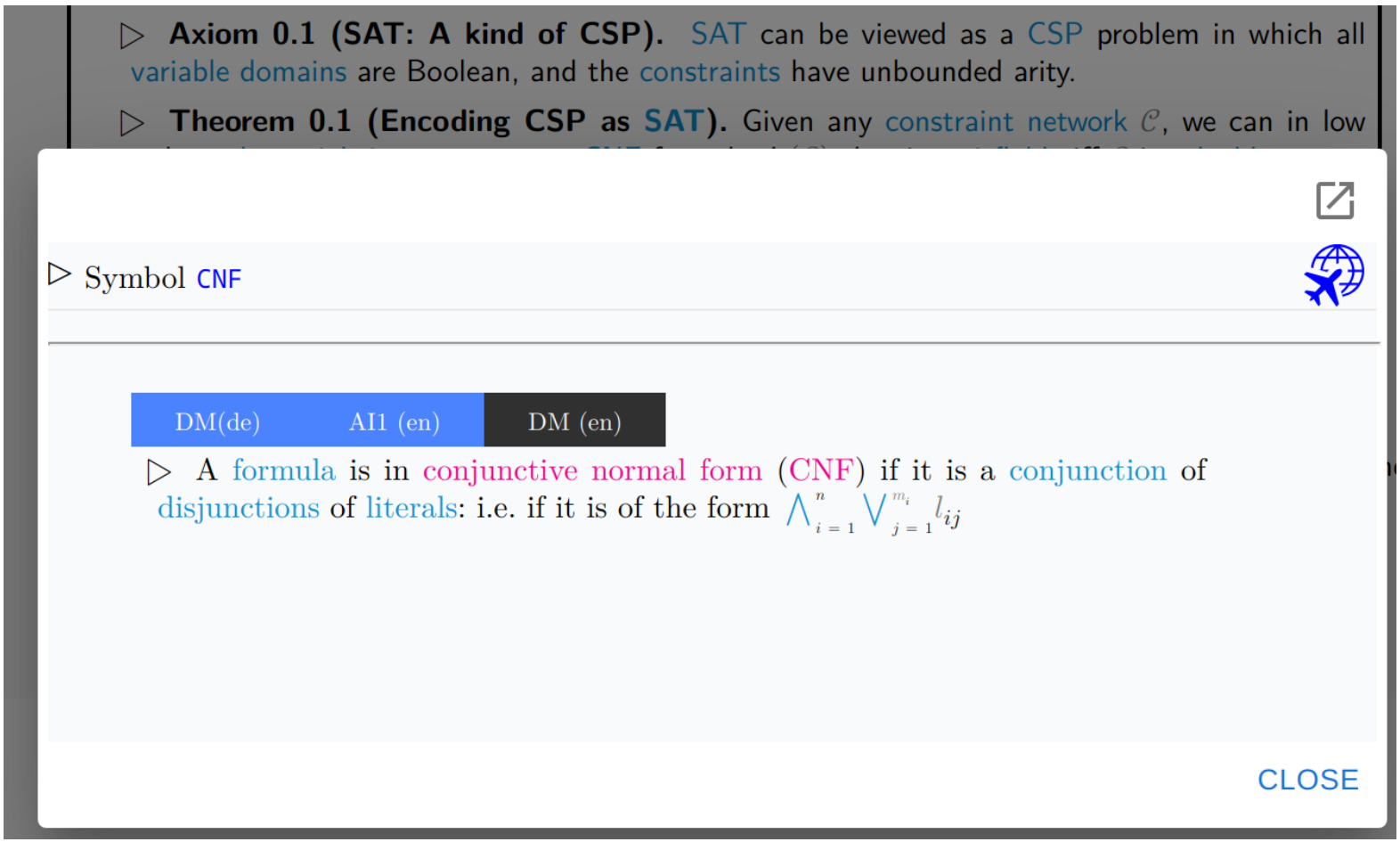
- **Example 4.10 (More Definitions on Click).** Clicking on a (cyan) term reference shows us more definitions from other contexts.



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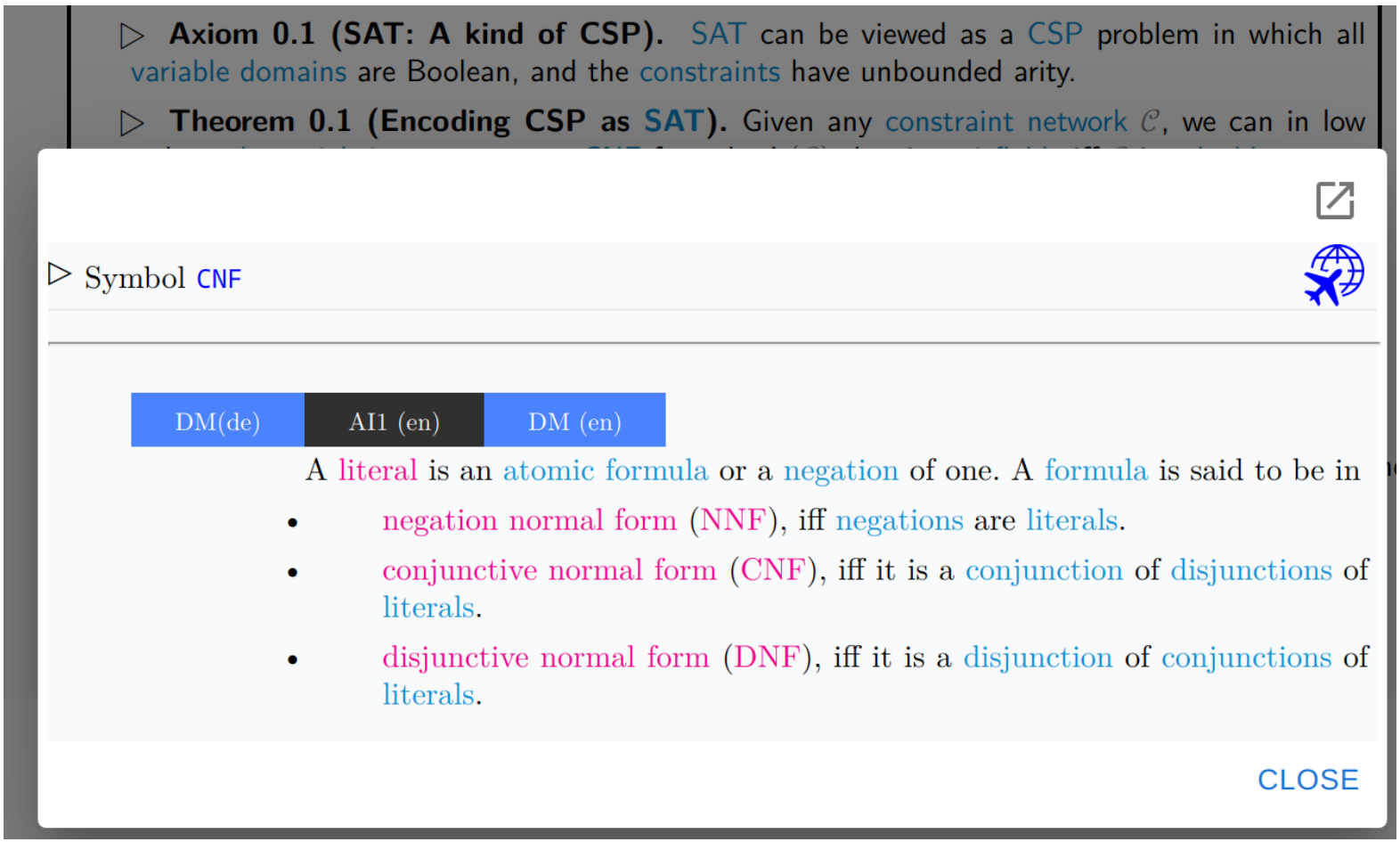

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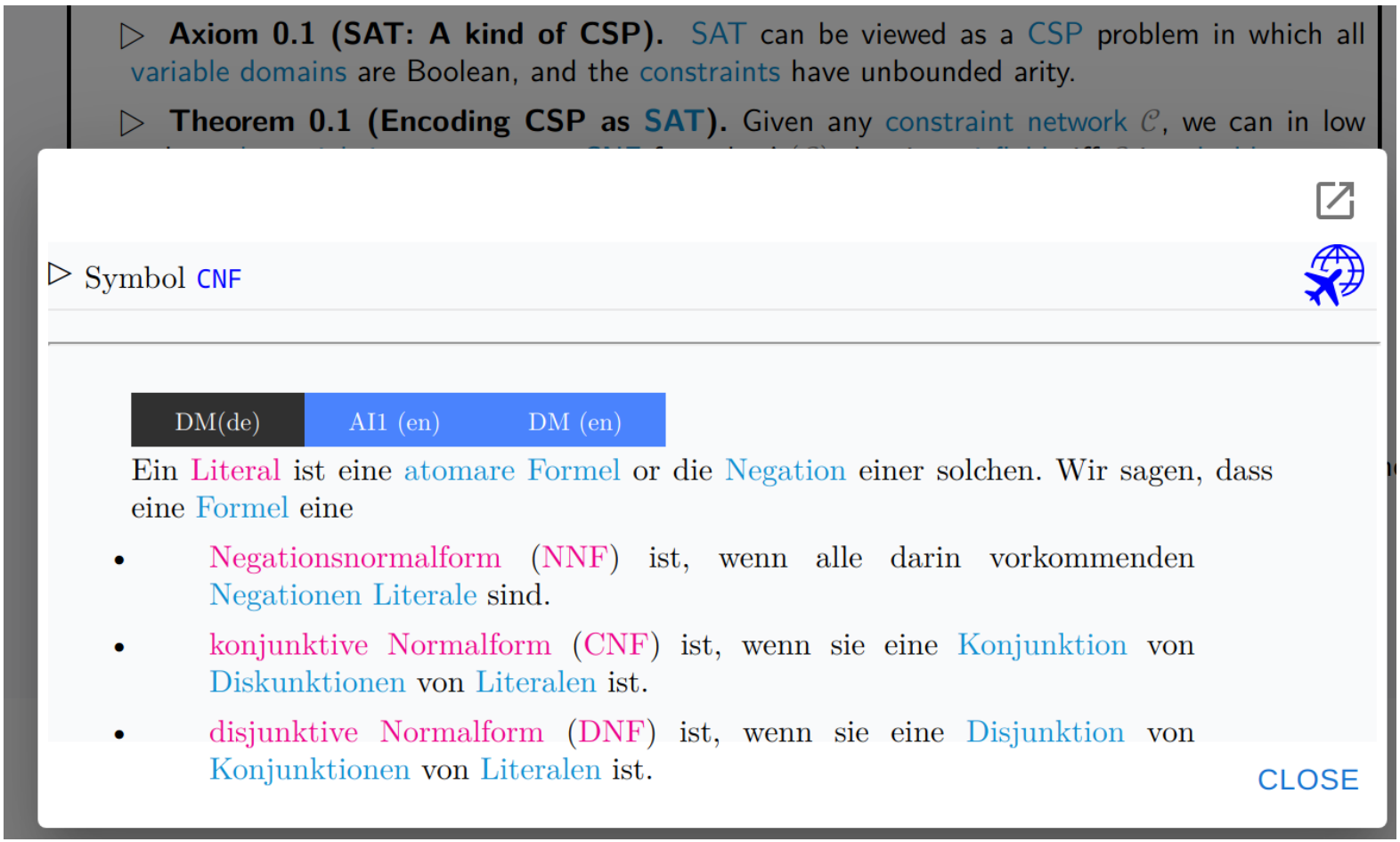

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- **Example 4.19 (More Definitions on Click).** Clicking on a (cyan) term reference shows us more definitions from other contexts.
- **Example 4.20 (Guided Tour).** A guided tour for a concept c assembles definitions/etc. into a self-contained mini-course culminating at c.

$c =$
countable $\rightsquigarrow$

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- . . . your idea here . . . (the sky is the limit)

(Practice/Remedial) Problems Everywhere

- **Problem:** Learning requires a mix of understanding and test-driven practice.
- **Idea:** ALeA supplies targeted practice problems everywhere.
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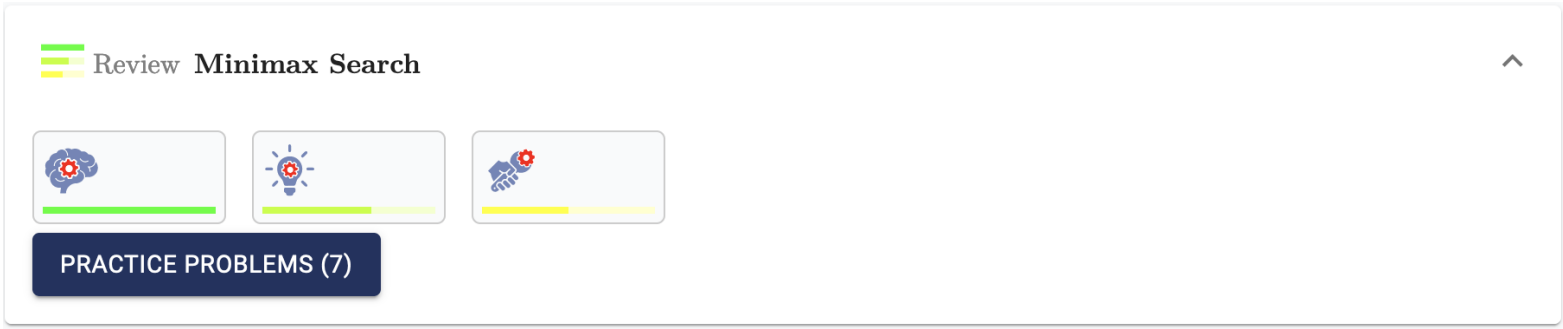

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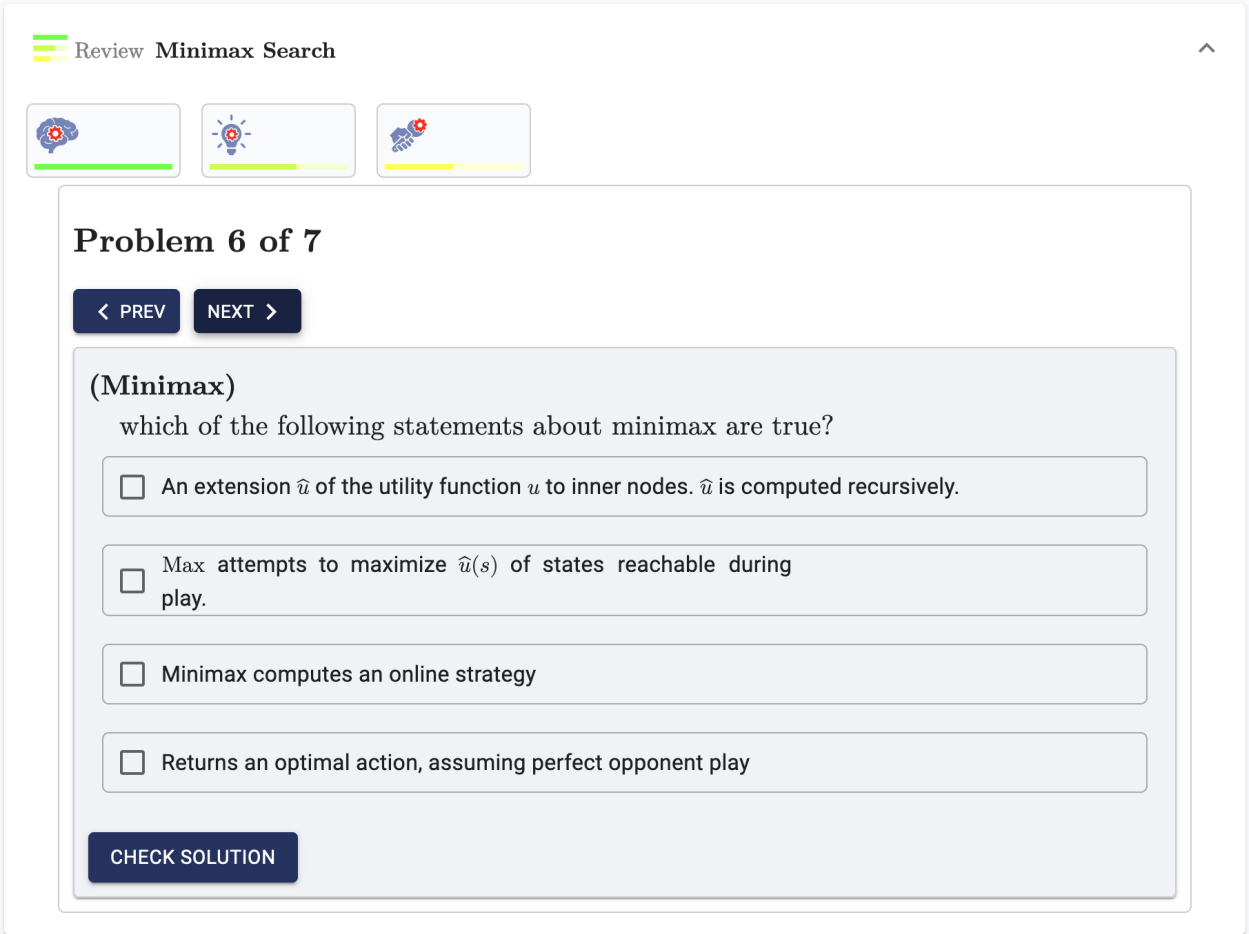
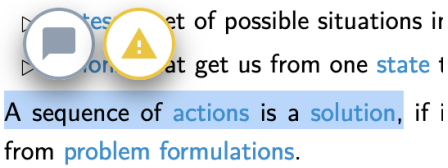
  - Click to extend it for details.
  - Practice problems as usual. (targeted to your specific competency)



Localized Interactions with the Community

- Selecting text brings up localized – i.e. anchored on the selection – interactions:



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  - report an error to the course authors/instructors

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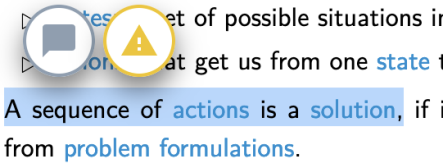
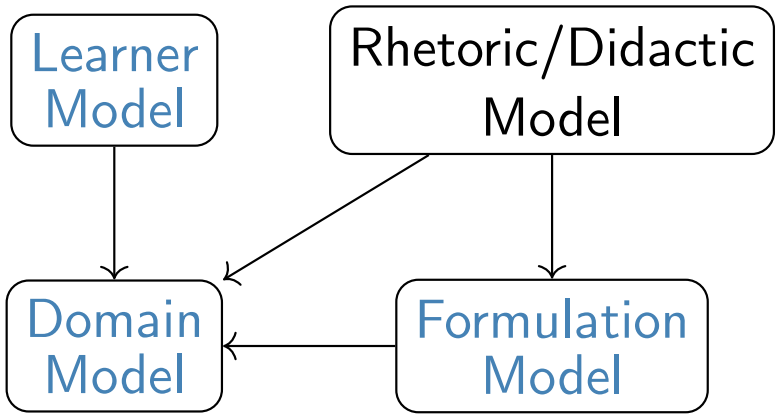


  - post a (public) comment or take (private) note
  - report an error to the course authors/instructors
- Localized comments induce a thread in the ALeA forum (like the StudOn Forum, but targeted towards specific learning objects.)

- Answering questions gives karma ≙ a public measure of user helpfulness.
- Notes can be anonymous (⇝ generate no karma)

ALeA$\widehat{=}$ Data-Driven & AI-enabled Learning Assistance

- **Idea:** Do what a teacher does!
  Use/maintain four models:

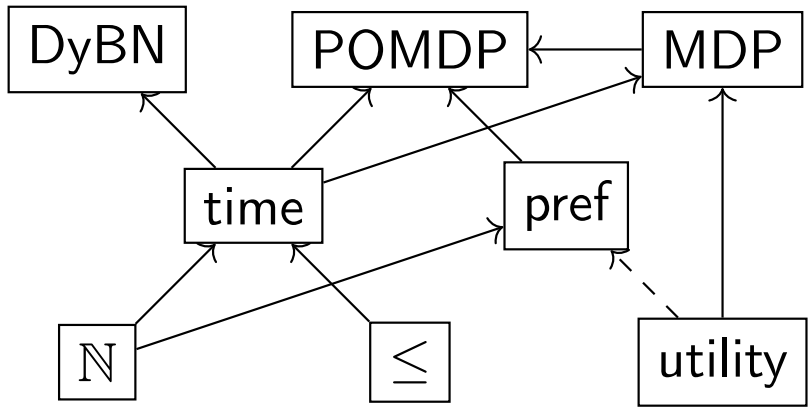


(Good) teachers

- understand the objects and their properties they are talking about
- have readimade formulations how to convey them best
- and understand how these best work together
- model what the learners already know/understand and adapts them accordingly

ALeA$\widehat{=}$ Data-Driven & AI-enabled Learning Assistance

- **Idea:** Do what a teacher does!
  Use/maintain four models:
- **Ingredient 1:** Domain model $\widehat{=}$ knowledge/theory graph

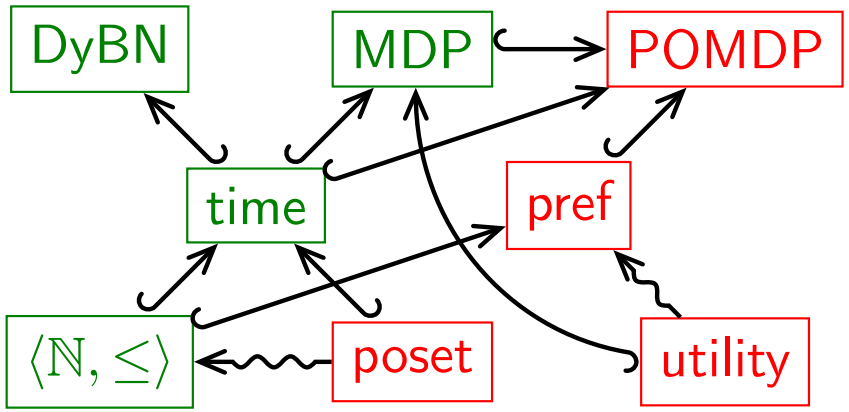


A theory graph provides (modular representation of the domain)

- symbols with URIs for all concepts, objects, and relations
- definitions, notations, and verbalizations for all symbols
- "object-oriented inheritance" and views between theories.

ALeA$\widehat{=}$ Data-Driven & AI-enabled Learning Assistance

- **Idea:** Do what a teacher does! Use/maintain four models:
- **Ingredient 1:** Domain model $\widehat{=}$ knowledge/theory graph
- **Ingredient 2:** Learner model $\widehat{=}$ adding competency estimations



The learner model is a function from learner IDs $\times$ symbol URIs to competency values

- competency comes in six cognitive dimensions: `remember`, `understand`, `analyze`, `evaluate`, `apply`, and `create`.
- ALeA logs all learner interactions (keeps data learner-private)
- each interaction updates the learner model function.

ALeA≙ Data-Driven & AI-enabled Learning Assistance

- **Idea:** Do what a teacher does! Use/maintain four models:
- **Ingredient 1:** Domain model ≙ knowledge/theory graph
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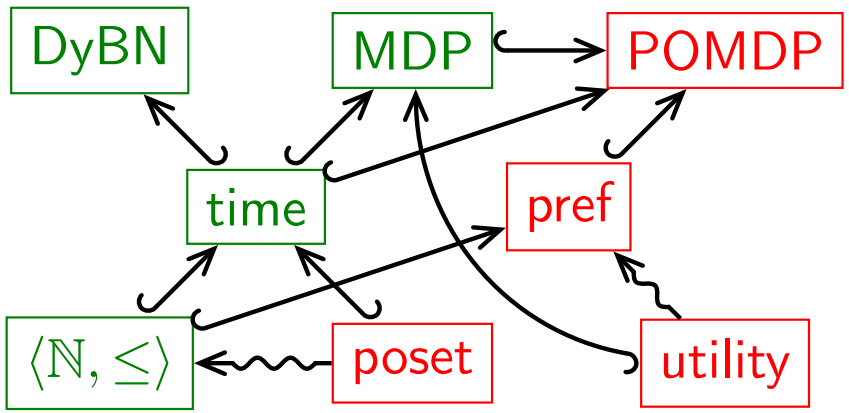
- **Ingredient 3:** A collection of ready-formulated learning objects



Learning objects are the text fragments learners see and interact with; they are structured by

- didactic relations, e.g. tasks have prerequisites and learning objectives
- rhetoric relations, e.g. introduction, elaboration, and transition

ALeA≙ Data-Driven & AI-enabled Learning Assistance

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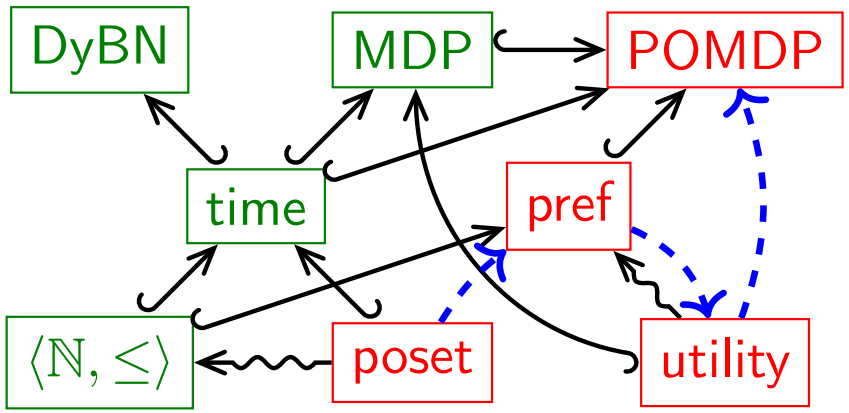
- **Ingredient 4:** Educational dialogue planner ⇝ guided tours

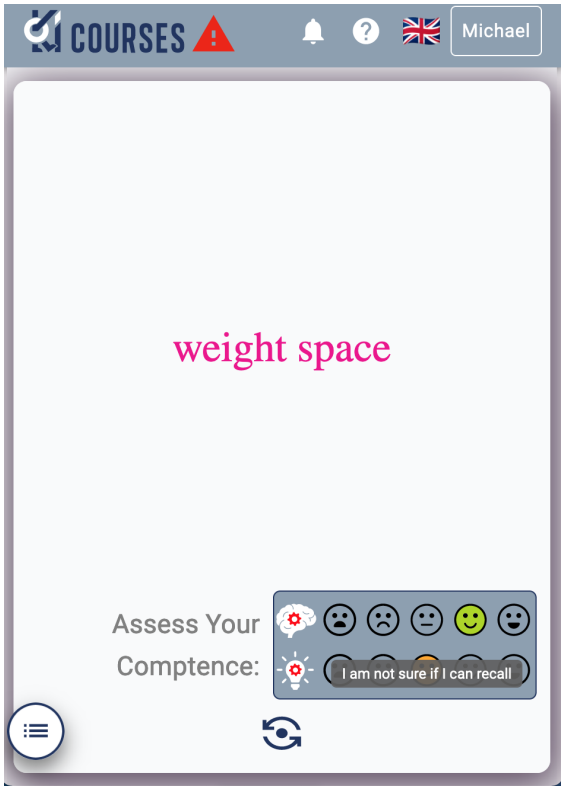


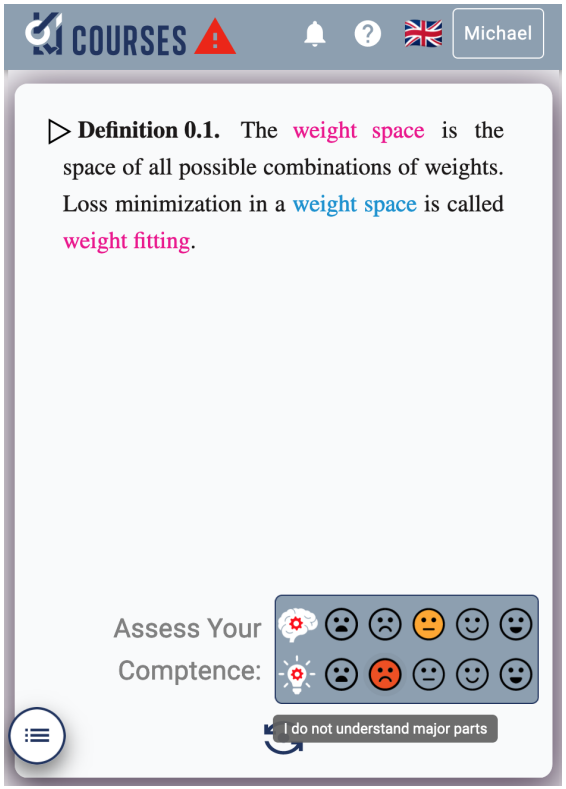
The dialogue planner assembles learning objects into active course material using

- the domain model and didactic relations to determine the order of LOs
- the learner model to determine what to show
- the rhetoric relations to make the dialogue coherent

New Feature: Drilling with Flashcards

- Flashcards challenge you with a task (term/problem) on the front...





...and the definition/answer is on the back.

- Self-assessment updates the learner model (before/after)
- **Idea:** Challenge yourself to a card stack, keep drilling/assessing flashcards until the learner model eliminates all.
- **Bonus:** Flashcards can be generated from existing semantic markup (educational equivalent to free beer)

Learner Data and Privacy in ALeA

- **Observation:** Learning support services in ALeA use the learner model; they
  - need the learner model data to adapt to the invidivual learner!
  - collect learner interaction data (to update the learner model)
- **Consequence:** You need to be logged in (via your FAU IDM credentials) for useful learning support services!

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- **ALeA Promise:** The ALeA team does the utmost to keep your personal data safe. (SSO via FAU IDM/eduGAIN, ALeA trust zone)
- **ALeA Privacy Axioms:**
  1. ALeA only collects learner models data about logged in users.
  2. Personally identifiable learner model data is only accessible to its subject (delegation possible)
  3. Learners can always query the learner model about its data.
  4. All learner model data can be purged without negative consequences (except usability deterioration)
  5. Logging into ALeA is completely optional.
- **Observation:** Authentication for bonus quizzes are somewhat less optional, but you can always purge the learner model later.

Concrete Todos for ALeA

- **Recall:** You will use ALeA for the prepquizzes (or lose bonus points)
  All other use is optional. (but AI-supported pre/postparation can be helpful)
- To use the ALeA system, you will have to log in via SSO: (do it now)
  - go to `https://courses.voll-ki.fau.de/course-home/ai-1`,
  - in the upper right hand corner you see 

,
  - log in via your FAU IDM credentials. (you should have them by now)
  - You get access to your personal ALeA profile via 

  (plus feature notifications, manual, and language chooser)

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    (plus feature notifications, manual, and language chooser)
- **Problem:** Most ALeA services depend on the learner model. (to adapt to you)
- **Solution:** Initialize your learner model with your educational history!
  - **Concretely**: enter taken CS courses (FAU equivalents) and grades.
  - ALeA uses that to estimate your CS/AI competencies. (for your benefit)
  - then ALeA knows about you; I don't! (ALeA trust zone)

Chapter 2
Artificial Intelligence – Who?, What?, When?, Where?, and Why?

Plot for this chapter

- Motivation, overview, and finding out what you already know
  - What is Artificial Intelligence?
  - What has AI already achieved?
  - A (very) quick walk through the AI-1 topics.
  - How can you get involved with AI at KWARC?

2.1 What is Artificial Intelligence?

What is Artificial Intelligence? Definition

- **Definition 1.1 (According to Wikipedia).** Artificial Intelligence (AI) is intelligence exhibited by machines
- **Definition 1.2 (also).** Artificial Intelligence (AI) is a sub-field of computer science that is concerned with the automation of intelligent behavior.
- **BUT:** it is already difficult to define intelligence precisely.
- **Definition 1.3 (Elaine Rich).** Artificial Intelligence (AI) studies how we can make the computer do things that humans can still do better at the moment.

What is Artificial Intelligence? Components

- **Elaine Rich:** AI studies how we can make the computer do things that humans can still do better at the moment.
- This needs a combination of

  the ability to learn

What is Artificial Intelligence? Components

- **Elaine Rich:** AI studies how we can make the computer do things that humans can still do better at the moment.
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Inference

What is Artificial Intelligence? Components

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Perception

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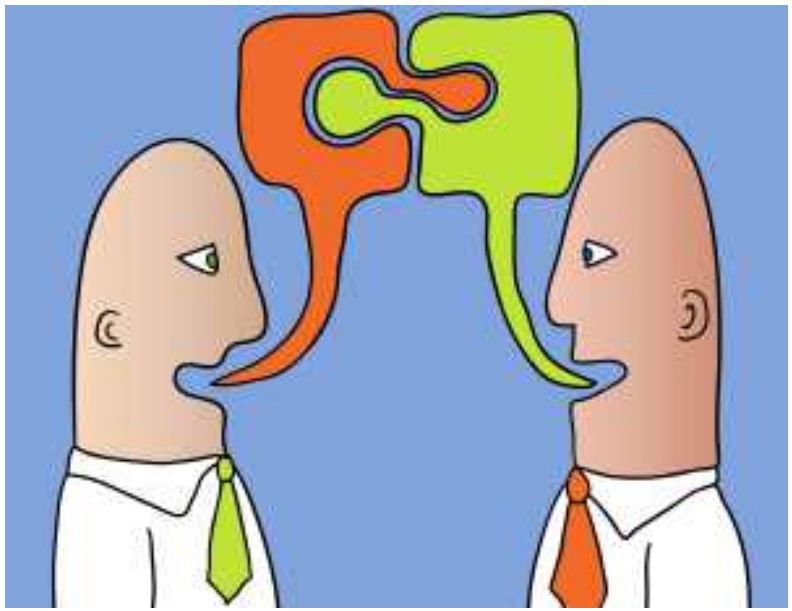
Language understanding



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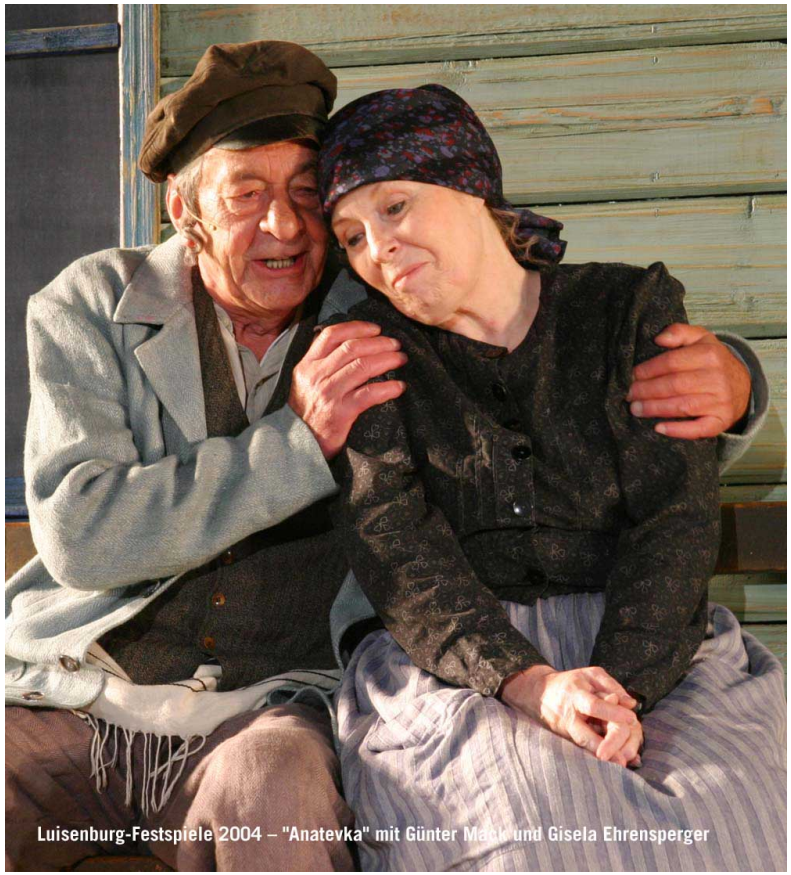
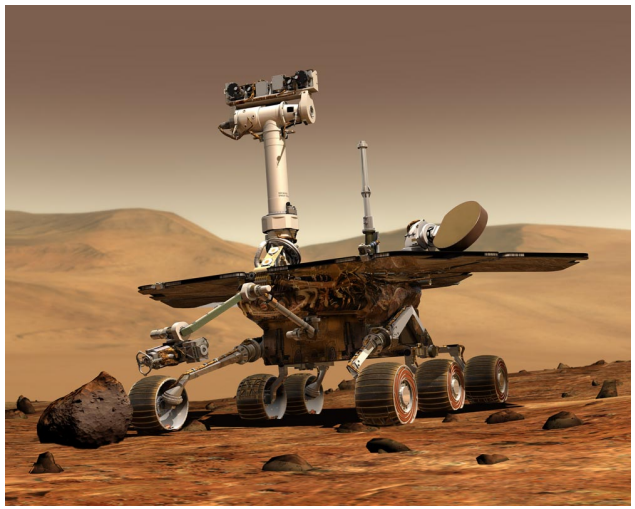
Emotion

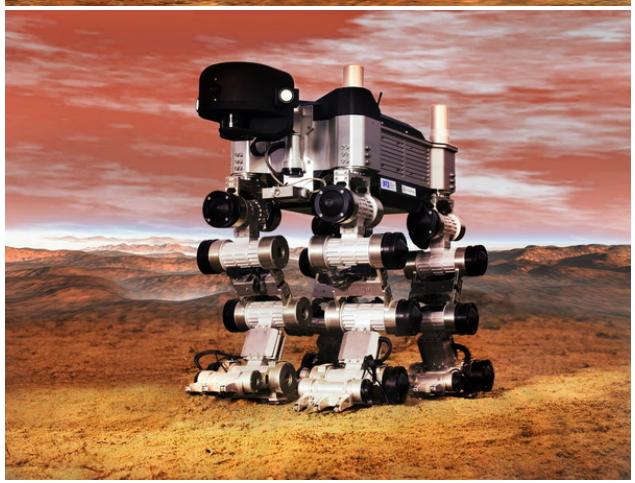


2.2 Artificial Intelligence is here today!

Artificial Intelligence is here today!

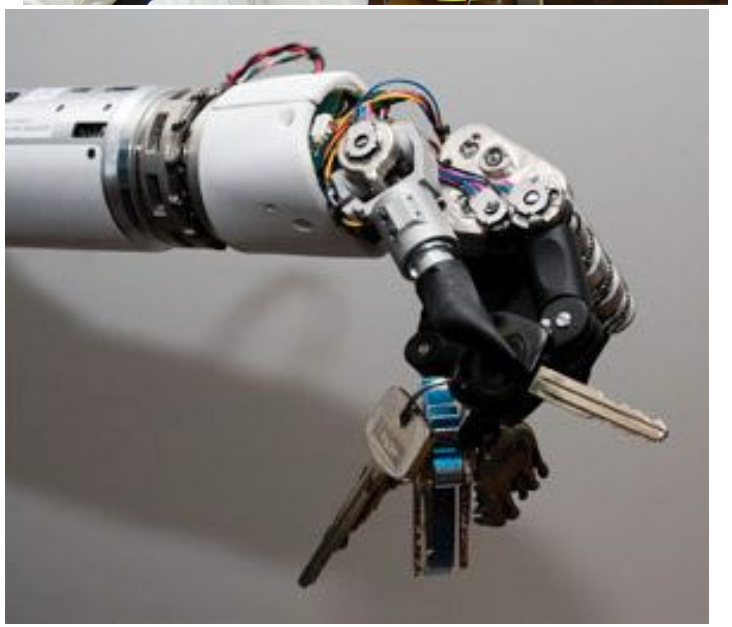
- in outer space
  - in outer space systems need autonomous control:
  - remote control impossible due to time lag
- in artificial limbs
- in household appliances
- in hospitals
- for safety/security





Artificial Intelligence is here today!

- in outer space
- in artificial limbs
  - the user controls the prosthesis via existing nerves, can e.g. grip a sheet of paper.
- in household appliances
- in hospitals
- for safety/security



Artificial Intelligence is here today!

- in outer space
- in artificial limbs
- in household appliances
  - The iRobot Roomba vacuums, mops, and sweeps in corners, . . . , parks, charges, and discharges.
  - general robotic household help is on the horizon.
- in hospitals
- for safety/security

Artificial Intelligence is here today!

- in outer space
- in artificial limbs
- in household appliances
- in hospitals
  - in the USA 90% of the prostate operations are carried out by RoboDoc
  - Paro is a cuddly robot that eases solitude in nursing homes.
- for safety/security

Artificial Intelligence is here today!

- in outer space
- in artificial limbs
- in household appliances
- in hospitals
- for safety/security
  - e.g. Intel verifies correctness of all chips after the "Pentium 5 disaster"

"It's the latest innovation in office safety.
When your computer crashes, an air bag is activated
so you won't bang your head in frustration."

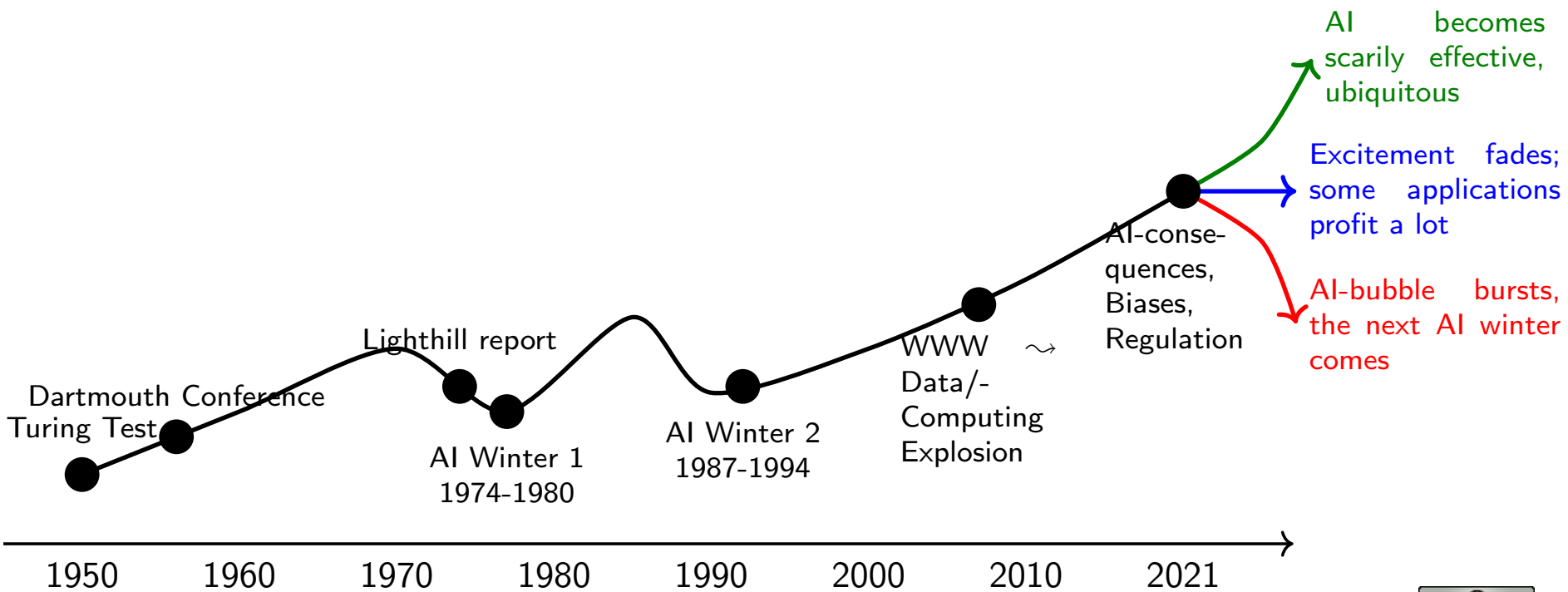
The AI Conundrum

- **Observation:** Reserving the term "Artificial Intelligence" has been quite a land grab!
- **But:** researchers at the Dartmouth Conference (1956) really thought they would solve/reach AI in two/three decades.
- **Consequence:** AI still asks the big questions. (and still promises answers soon)
- **Another Consequence:** AI as a field is an incubator for many innovative technologies.
- **AI Conundrum:** Once AI solves a subfield it is called "computer science". (becomes a separate subfield of CS)
- **Example 2.1.** Functional/Logic Programming, automated theorem proving, Planning, machine learning, Knowledge Representation, ...
- **Still Consequence:** AI research was alternatingly flooded with money and cut off brutally.

The current AI Hype — Part of a longer Story

- The history of AI as a discipline has been very much tied to the amount of funding – that allows us to do research and development.

- A potted history of AI (AI summers and summers)



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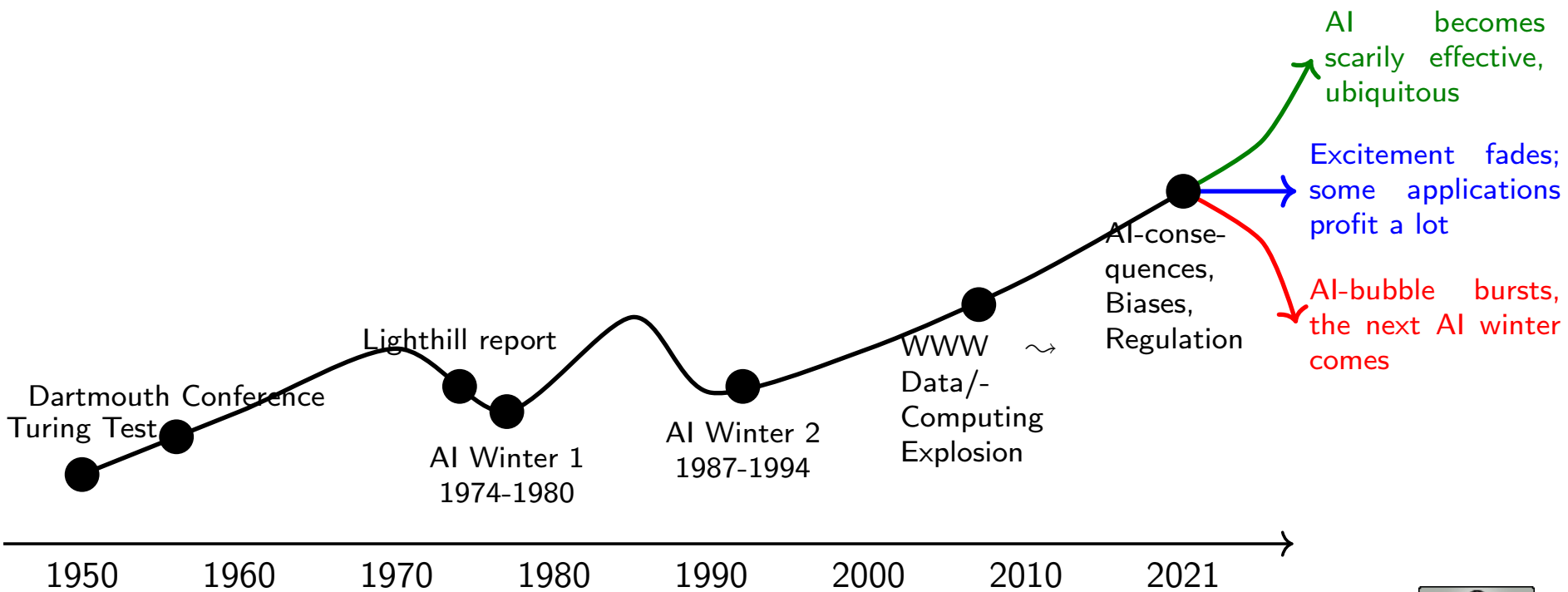
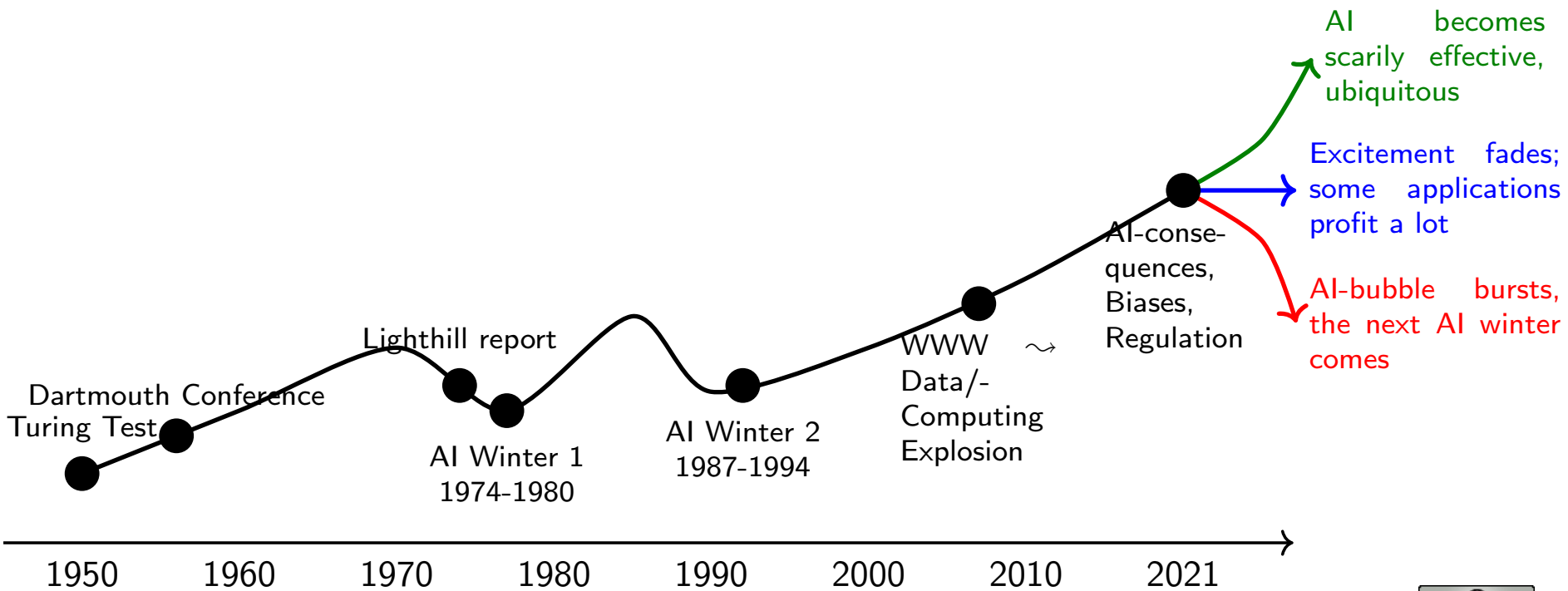


The current AI Hype — Part of a longer Story

- The history of AI as a discipline has been very much tied to the amount of funding – that allows us to do research and development.
- Funding levels are tied to public perception of success (especially for AI)
- **Definition 2.4.** An AI winter is a time period of low public perception and funding for AI,
  mostly because AI has failed to deliver on its – sometimes overblown – promises
  An AI summer is a time period of high public perception and funding for AI
- A potted history of AI (AI summers and summers)



2.3 Ways to Attack the AI Problem

Four Main Approaches to Artificial Intelligence

- **Definition 3.1.** Symbolic AI is a subfield of AI based on the assumption that many aspects of intelligence can be achieved by the manipulation of symbols, combining them into meaning-carrying structures (expressions) and manipulating them (using processes) to produce new expressions.

Four Main Approaches to Artificial Intelligence

- **Definition 3.5.** Symbolic AI is a subfield of AI based on the assumption that many aspects of intelligence can be achieved by the manipulation of symbols, combining them into meaning-carrying structures (expressions) and manipulating them (using processes) to produce new expressions.
- **Definition 3.6.** Statistical AI remedies the two shortcomings of symbolic AI approaches: that all concepts represented by symbols are crisply defined, and that all aspects of the world are knowable/representable in principle. Statistical AI adopts sophisticated mathematical models of uncertainty and uses them to create more accurate world models and reason about them.

Four Main Approaches to Artificial Intelligence

- **Definition 3.9.** Symbolic AI is a subfield of AI based on the assumption that many aspects of intelligence can be achieved by the manipulation of symbols, combining them into meaning-carrying structures (expressions) and manipulating them (using processes) to produce new expressions.
- **Definition 3.10.** Statistical AI remedies the two shortcomings of symbolic AI approaches: that all concepts represented by symbols are crisply defined, and that all aspects of the world are knowable/representable in principle. Statistical AI adopts sophisticated mathematical models of uncertainty and uses them to create more accurate world models and reason about them.
- **Definition 3.11.** Subsymbolic AI (also called connectionism or neural AI) is a subfield of AI that posits that intelligence is inherently tied to brains, where information is represented by a simple sequence pulses that are processed in parallel via simple calculations realized by neurons, and thus concentrates on neural computing.

Four Main Approaches to Artificial Intelligence

- **Definition 3.13.** Symbolic AI is a subfield of AI based on the assumption that many aspects of intelligence can be achieved by the manipulation of symbols, combining them into meaning-carrying structures (expressions) and manipulating them (using processes) to produce new expressions.
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- **Definition 3.15.** Subsymbolic AI (also called connectionism or neural AI) is a subfield of AI that posits that intelligence is inherently tied to brains, where information is represented by a simple sequence pulses that are processed in parallel via simple calculations realized by neurons, and thus concentrates on neural computing.
- **Definition 3.16.** Embodied AI posits that intelligence cannot be achieved by reasoning about the state of the world (symbolically, statistically, or connectivist), but must be embodied i.e. situated in the world, equipped with a "body" that can interact with it via sensors and actuators. Here, the main method for realizing intelligent behavior is by learning from the world.

Two ways of reaching Artificial Intelligence?

- We can classify the AI approaches by their coverage and the analysis depth(they are complementary)

Analysis ↑ vs. Coverage →	Narrow	Wide
Deep	symbolic AI-1	not there yet cooperation?
Shallow	no-one wants this	statistical/sub symbolic AI-2

- **This semester** we will cover foundational aspects of symbolic AI (deep/narrow processing)
- **next semester** concentrate on statistical/subsymbolic AI. (shallow/wide-coverage)

Environmental Niches for both Approaches to AI

- **Observation:** There are two kinds of applications/tasks in AI
  - Consumer tasks: consumer grade applications have tasks that must be fully generic and wide coverage. (e.g. machine translation like Google Translate)
  - Producer tasks: producer grade applications must be high-precision, but can be domain-specific (e.g. multilingual documentation, machinery-control, program verification, medical technology)

Precision		
100%	Producer Tasks	
50%	Consumer Tasks	
	$10^{3\pm1}$ Concepts	$10^{6\pm1}$ Concepts **Coverage**

after Aarne Ranta [Ran17].

- **General Rule:** Subsymbolic AI is well suited for consumer tasks, while symbolic AI is better suited for producer tasks.
- A domain of producer tasks I am interested in: mathematical/technical documents.

2.4 Strong vs. Weak AI

Strong AI vs. Narrow AI

- **Definition 4.1.** With the term narrow AI (also weak AI, instrumental AI, applied AI) we refer to the use of software to study or accomplish *specific* problem solving or reasoning tasks (e.g. playing chess/go, controlling elevators, composing music, ...)
- **Definition 4.2.** With the term strong AI (also full AI, AGI) we denote the quest for software performing at the full range of human cognitive abilities.
- **Definition 4.3.** Problems requiring strong AI to solve are called AI hard, and AI complete, iff AGI should be able to solve them all.
- **In short:** We can characterize the difference intuitively:
  - narrow AI: What (most) computer scientists think AI is / should be.
  - strong AI: What Hollywood authors think AI is / should be.
- **Needless to say** we are only going to cover narrow AI in this course!

A few words on AGI...

- The conceptual and mathematical framework (agents, environments etc.) is the same for strong AI and weak AI.
- AGI research focuses mostly on abstract aspects of machine learning (reinforcement learning, neural nets) and decision/game theory ("which goals should an AGI pursue?").
- Academic respectability of AGI fluctuates massively, recently increased (again). (correlates somewhat with AI winters and golden years)
- Public attention increasing due to talk of "existential risks of AI" (e.g. Hawking, Musk, Bostrom, Yudkowsky, Obama, ...)
- **Kohlhase's View:** Weak AI is here, strong AI is very far off. (not in my lifetime)
- ⚠ : But even if that is true, weak AI will affect all of us deeply in everyday life.
- **Example 4.4.** You should not train to be an accountant or truck driver! (bots will replace you soon)

AGI Research and Researchers

- "Famous" research(ers) / organizations
  - MIRI (Machine Intelligence Research Institute), Eliezer Yudkowsky (Formerly known as "Singularity Institute")
  - Future of Humanity Institute Oxford (Nick Bostrom),
  - Google (Ray Kurzweil),
  - AGIRI / OpenCog (Ben Goertzel),
  - `petrl.org` (People for the Ethical Treatment of Reinforcement Learners).
    (Obviously somewhat tongue-in-cheek)
- ⚠ Be highly skeptical about any claims with respect to AGI! (Kohlhase's View)

2.5 AI Topics Covered

Topics of AI-1 (Winter Semester)

- Getting Started
  - What is Artificial Intelligence? (situating ourselves)
  - Logic programming in Prolog (An influential paradigm)
  - Intelligent Agents (a unifying framework)
- Problem Solving
  - Problem Solving and search (Black Box World States and Actions)
  - Adversarial search (Game playing) (A nice application of search)
  - constraint satisfaction problems (Factored World States)
- Knowledge and Reasoning
  - Formal Logic as the mathematics of Meaning
  - Propositional logic and satisfiability (Atomic Propositions)
  - First-order logic and theorem proving (Quantification)
  - Logic programming (Logic + Search$\rightsquigarrow$ Programming)
  - Description logics and semantic web
- Planning
  - Planning Frameworks
  - Planning Algorithms
  - Planning and Acting in the real world

Topics of AI-2 (Summer Semester)

- Uncertain Knowledge and Reasoning
  - Uncertainty
  - Probabilistic reasoning
  - Making Decisions in Episodic Environments
  - Problem Solving in Sequential Environments
- Foundations of machine learning
  - Learning from Observations
  - Knowledge in Learning
  - Statistical Learning Methods
- Communication (If there is time)
  - Natural Language Processing
  - Natural Language for Communication

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- **BTW:** There will also be an AI2SysProj next semester! (another chance)

2.6 AI in the KWARC Group

The KWARC Research Group

- **Observation:** The ability to represent knowledge about the world and to draw logical inferences is one of the central components of intelligent behavior.
- **Thus:** reasoning components of some form are at the heart of many AI systems.
- **KWARC Angle:** Scaling up (web-coverage) without dumbing down (too much)
  - Content markup instead of full formalization (too tedious)
  - User support and quality control instead of "The Truth" (elusive anyway)
  - use Mathematics as a test tube (⚠ Mathematics $\widehat{=}$ Anything Formal ⚠)
  - care more about applications than about philosophy (we cannot help getting this right anyway as logicians)
- The KWARC group was established at Jacobs Univ. in 2004, moved to FAU Erlangen in 2016
- see `http://kwarc.info` for projects, publications, and links

Overview: KWARC Research and Projects

Applications: eMath 3.0, Active Documents, Active Learning, Semantic Spreadsheets/CAD/CAM, Change Mangagement, Global Digital Math Library, Math Search Systems, SMGloM: Semantic Multilingual Math Glossary, Serious Games, ...

Foundations of Math:	**KM & Interaction**:	**Semantization**:
▶ MathML, *OpenMath*	▶ Semantic Interpretation (aka. Framing)	▶ LaTeXML: LaTeX $\rightsquigarrow$ XML
▶ advanced Type Theories	▶ math-literate interaction	▶ sTeX: Semantic LaTeX
▶ MMT: Meta Meta Theory	▶ MathHub: math archives & active docs	▶ invasive editors
▶ Logic Morphisms/Atlas	▶ Active documents: embedded semantic services	▶ Context-Aware IDEs
▶ Theorem Prover/CAS Interoperability	▶ Model-based Education	▶ Mathematical Corpora
▶ Mathematical Models/Simulation		▶ Linguistics of Math
		▶ ML for Math Semantics Extraction

Foundations: Computational Logic, Web Technologies, OMDoc/MMT

Research Topics in the KWARC Group

- We are always looking for bright, motivated KWARCies.
- We have topics in for all levels! (Enthusiast, Bachelor, Master, Ph.D.)
- List of current topics: `https://gl.kwarc.info/kwarc/thesis-projects/`
  - Automated Reasoning: Maths Representation in the Large
  - Logics development, (Meta)^n-Frameworks
  - Math Corpus Linguistics: Semantics Extraction
  - Serious Games, Cognitive Engineering, Math Information Retrieval, Legal Reasoning, ...
  - ...last but not least: KWARC is the home of ALEA!
- We always try to find a topic at the intersection of your and our interests.
- We also sometimes have positions!. (HiWi, Ph.D.: $\frac{1}{2}$ E-13, PostDoc: full E-13)

References I

[Nor+18a] Emily Nordmann et al. *Lecture capture: Practical recommendations for students and lecturers*. 2018. URL: https://osf.io/huydx/download.

[Nor+18b] Emily Nordmann et al. *Vorlesungsaufzeichnungen nutzen: Eine Anleitung für Studierende*. 2018. URL: https://osf.io/e6r7a/download.

[Ran17] Aarne Ranta. *Automatic Translation for Consumers and Producers*. Presentation given at the Chalmers Initiative Seminar. 2017. URL: https://www.grammaticalframework.org/~aarne/mt-digitalization-2017.pdf.

[RN09] Stuart Russell and Peter Norvig. *Artificial Intelligence: A Modern Approach*. 3rd. Prentice Hall Press, 2009. ISBN: 0136042597, 9780136042594.

[She24] Esther Shein. 2024. URL: https://cacm.acm.org/news/the-impact-of-ai-on-computer-science-education/.