Artificial Intelligence 1
Winter Semester 2024/25

– Lecture Notes –
Admin & Overview

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This document contains the administrative information and overview chapter of the course notes for the course "Artificial Intelligence 1" held at FAU Erlangen-Nürnberg in the Winter Semesters 2016/17 ff. Other parts of the lecture notes can be found at `http://kwarc.info/teaching/AI/notes-*.pdf`.

Contents

Chapter 1

Preliminaries

In this chapter, we want to get all the organizational matters out of the way, so that we can get into the discussion of artificial intelligence content unencumbered. We will talk about the necessary administrative details, go into how students can get most out of the course, talk about where the various resources provided with the course can be found, and finally introduce the ALEA system, an experimental – using AI methods – learning support system for the AI course.

1.1 Administrative Ground Rules

We will now go through the ground rules for the course. This is a kind of a social contract between the instructor and the students. Both have to keep their side of the deal to make learning as efficient and painless as possible.

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)
- **Skillset Prerequisite:** Coping with mathematical formulation of the structures
  - Mathematics is the language of science (in particular computer science)
  - It allows us to be very precise about what we mean. (good for you)
- **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!
- **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)

Note: I do not literally presuppose the courses on the slide above – most of you do not have a bachelor's degree from FAU, so you cannot have taken them. And indeed some of the content of these courses is irrelevant for AI-1. Stating these courses is just the easiest way to specifying what content I will be building on – and any graduate courses has to build on something.

Many of you will have taken the moral equivalent of these courses in your undergraduate studies at your home university. If you did not, you will have to somehow catch up on the content as we go along in AI-1. This should be possible with enough motivation.
There are essentially three skillsets that are essential for AI-1:

1. A solid understanding and practical skill in programming (whatever programming language)
2. A good understanding and practice in using mathematical language to represent complex structures
3. A solid understanding of formal languages and grammars, as well as applied complexity theory (basics of theoretical computer science).

Without (catching up on) these the AI-1 course will be quite frustrating and hard.

We will briefly go over the most important topics in **??** to synchronize concepts and notation. Note that if you do not have a formal education in courses like the ones mentioned above you will very probably have to do significant remedial work.
Now we come to a topic that is always interesting to the students: the grading scheme.

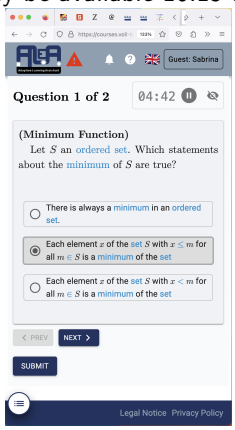
Assessment, Grades

- **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.
- **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 1.1.1.** 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)

Due to the current AI hype, the course Artificial Intelligence is very popular and thus many degree programs at FAU have adopted it for their curricula. Sometimes the course setup that fits for the CS program does not fit the other's very well, therefore there are some special conditions. I want to state here.

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 course creditcredits need to be divisible by five $\rightsquigarrow 7.5 + 7.5 = 15$.

I can only warn of what I am aware, so if your degree program lets you jump through extra hoops, please tell me and then I can mention them here.

1.2 Getting Most out of AI-1

In this section we will discuss a couple of measures that students may want to consider to get most out of the AI-1 course.

None of the things discussed in this section – homeworks, tutorials, study groups, and attendance – are mandatory (we cannot force you to do them; we offer them to you as learning opportunities), but most of them are very clearly correlated with success (i.e. passing the exam and getting a good grade), so taking advantage of them may be in your own interest.

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.
- 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)

It is very well-established experience that without doing the homework assignments (or something

similar) on your own, you will not master the concepts, you will not even be able to ask sensible questions, and take very little home from the course. Just sitting in the course and nodding is not enough!

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.
- **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.
- **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!)

If you have questions please make sure you discuss them with the instructor, the teaching assistants, or your fellow students. There are three sensible venues for such discussions: online in the lectures, in the tutorials, which we discuss now, or in the course forum – see below. Finally, it is always a very good idea to form study groups with your friends.

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.
- **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 1.2.1.** 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)

As we said above, almost all of the components of the AI-1 course are optional. That even applies to attendance. But make no mistake, attendance is important to most of you. Let me explain, . . .

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

But what if you are not in a lecture or tutorial and want to find out more about the AI-1 topics?

Textbook, Handouts and Information, Forums, Videos

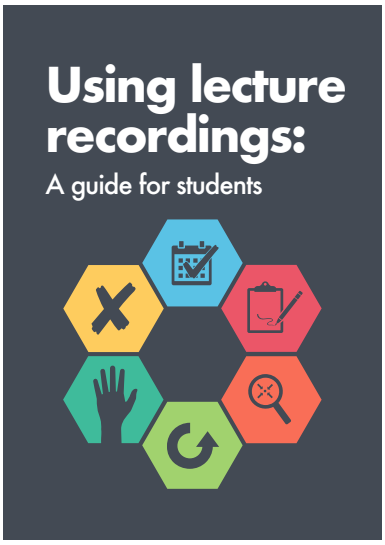
- **Textbook:** *Russel/Norvig: Artificial Intelligence, A modern Approach* [RN09].
  - basically "broad but somewhat shallow"
  - great to get intuitions on the basics of AI

  Make sure that you read the edition ≥ 3 ↜ vastly improved over ≤ 2.
- **Lecture notes:** will be posted at `https://kwarc.info/teaching/AI`
  - more detailed than [RN09] in some areas
  - I mostly prepare them as we go along (semantically preloaded ⇝ research resource)
  - please e-mail me any errors/shortcomings you notice. (improve for the group)
- **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`
- **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!)

FAU has issued a very insightful guide on using lecture videos. It is a good idea to heed these recommendations, even if they seem annoying at first.

Practical recommendations on Lecture Videos

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



Attend lectures.

Take notes.

Be specific.

Catch up.

Ask for help.

Don't cut corners.

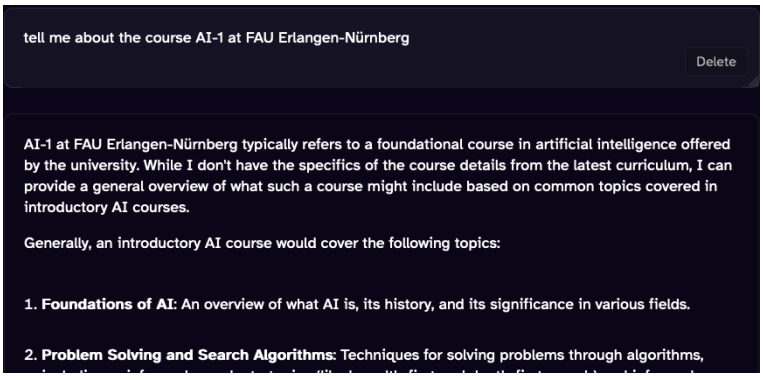
NOT a Resource for : LLMs – AI-based tools like ChatGPT

▷ **Definition 1.3.1.** A large language model (LLM) is a computational model capable of language generation or other natural language processing tasks.

▷ **Example 1.3.2.** OpenAI's GPT, Google's Bard, and Meta's Llama.

▷ **Definition 1.3.3.** 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 1.3.4 (ChatGPT talks about AI-1).** (but remains vague)



▷ **Note:** LLM-based chatbots invent *every word*! (suprpisingly often correct)

▷ **Example 1.3.5 (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!

▷ **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)

▷ **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

In this section we introduce the ALeA (Adaptive Learning Assistant) system, a learning support system we have developed using symbolic AI methods – the stuff we learn about in AI-1 – and which we will use to support students in the course. As such, ALeA does double duty in the AI-1 course it supports learning activities and serves as a showcase, what symbolic AI methods can to in an important application.

ALeA: Adaptive Learning Assistant

▷ **Idea:** Use AI methods to help teach/learn AI (AI4AI)

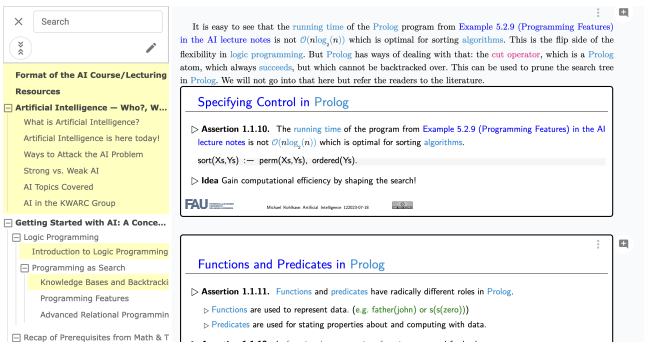
▷ **Concretely:** Provide HTML versions of the AI-1 slides/lecture notes and embed learning support services into them. (for pre/postparation of lectures)

▷ **Definition 1.4.1.** 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 1.4.2 (Course Notes).** ≙ Slides + Comments



⇝ yellow parts in table of contents (left) already covered in lectures.

The central idea in the AI4AI approach – using AI to support learning AI – and thus the ALeA system is that we want to make course materials – i.e. what we give to students for preparing and postparing lectures – more like teachers and study groups (only available 24/7) than like static books.

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

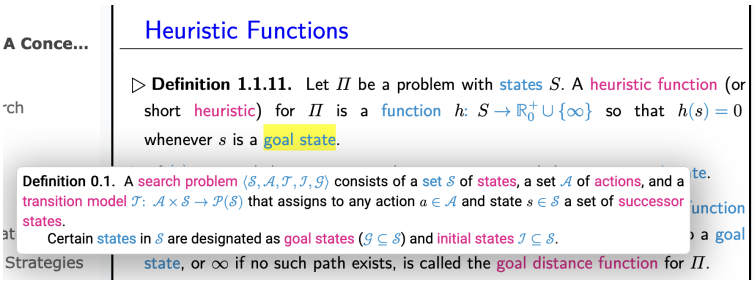
- ▷ (some) students use the system actively (our logs tell us)
- ▷ reviews are mostly positive/enthusiastic (error reports pour in)

The ALeA AI-1 page is the central entry point for working with the ALeA system. You can get to all the components of the system, including two presentations of the course contents (notes- and slides-centric ones), the flashcards, the localized forum, and the quiz dashboard.
We now come to the heart of the ALeA system: its learning support services, which we will now briefly introduce. Note that this presentation is not really sufficient to undertstand what you may be getting out of them, you will have to try them, and interact with them sufficiently that the learner model can get a good estimate of your competencies to adapt the results to you.

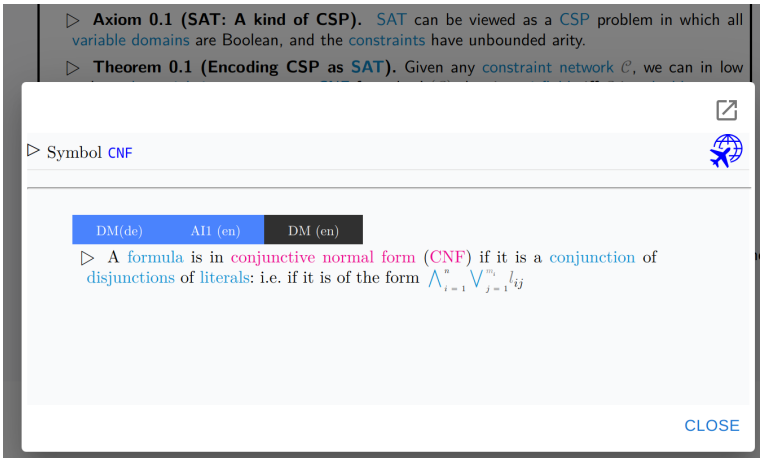
Learning Support Services in ALeA

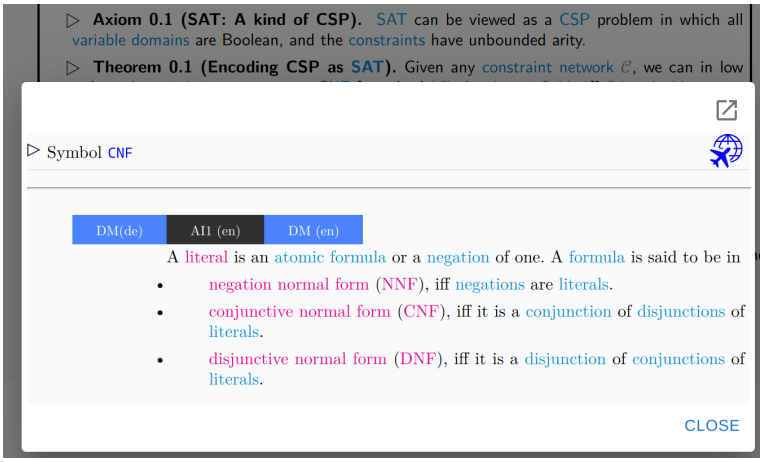
▷ **Idea:** Embed learning support services into active course materials.

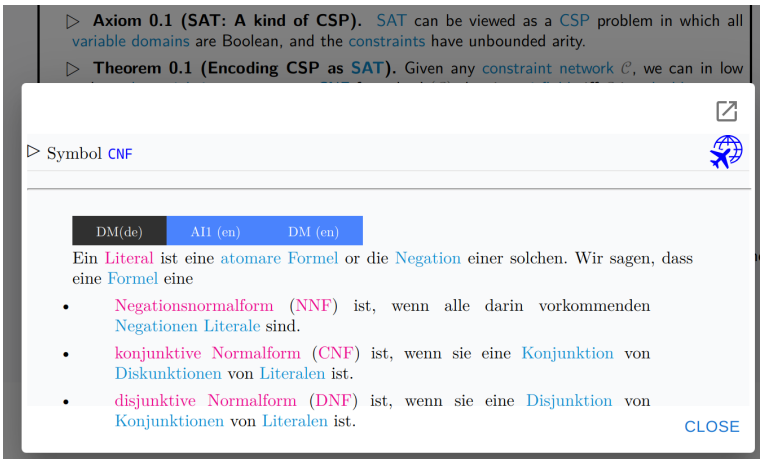
▷ **Example 1.4.3 (Definition on Hover).** Hovering on a (cyan) term reference reminds us of its definition. (even works recursively)



▷ **Example 1.4.4 (More Definitions on Click).** Clicking on a (cyan) term reference shows us more definitions from other contexts.

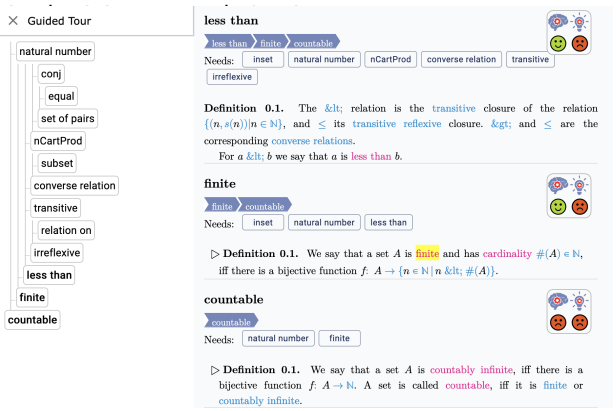






▷ **Example 1.4.5 (Guided Tour).** A guided tour for a concept c assembles definitions/etc. into a self-cont

c = countable ⇝



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

Note that this is only an initial collection of learning support services, we are constantly working on additional ones. Look out for feature notifications (

) on the upper right hand of the ALeA screen.

(Practice/Remedial) Problems Everywhere

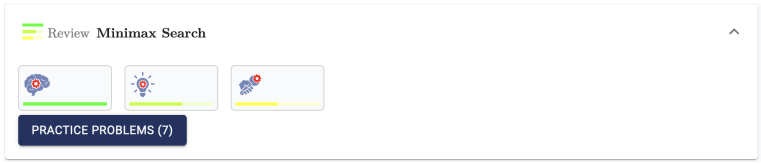
▷ **Problem:** Learning requires a mix of understanding and test-driven practice.

▷ **Idea:** ALeA supplies targeted practice problems everywhere.

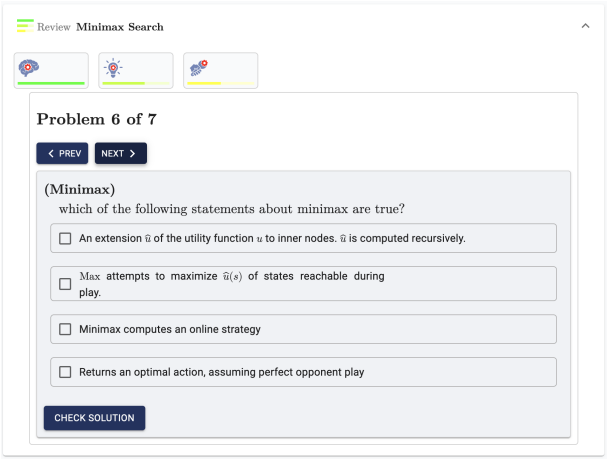
▷ **Concretely:** Revision markers at the end of sections.

▷ A relatively non-intrusive overview over competency

▷ Click to extend it for details.



▷ Practice problems as usual. (targeted to your specific competency)



While the learning support services up to now have been adressed to individual learners, we now turn to services addressed to communities of learners, ranging from study groups with three learners, to whole courses, and even – eventually – all the alumni of a course, if they have not de-registered from ALeA.

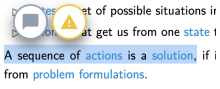
Currently, the community aspect of ALeA only consists in localized interactions with the course materials.

The ALeA system uses the semantic structure of the course materials to localize some interactions that are otherwise often from separate applications. Here we see two:

1. one for reporting content errors – and thus making the material better for all learners – and‘’
2. a localized course forum, where forum threads can be attached to learning objects.

Localized Interactions with the Community

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



▷ 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 $\widehat{=}$ a public measure of user helpfulness.

▷ Notes can be anonymous ($\rightsquigarrow$ generate no karma)

Let us briefly look into how the learning support services introduced above might work, focusing on where the necessary information might come from. Even though some of the concepts in the discussion below may be new to AI-1 students, it is worth looking into them. Bear with us as we try to explain the AI components of the ALeA system.

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

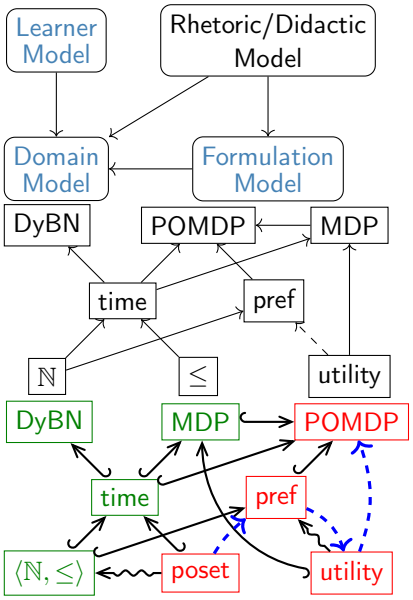
▷ **Idea:** Do what a teacher does! Use/maintain four models:

▷ **Ingredient 1:** Domain model $\widehat{=}$ knowledge/theory graph

▷ **Ingredient 2:** Learner model $\widehat{=}$ adding competency estimations

▷ **Ingredient 3:** A collection of ready-formulated learning objects

▷ **Ingredient 4:** Educational dialogue planner $\rightsquigarrow$ guided tours



(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

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.

The learner model is a function from learner IDs × 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.

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

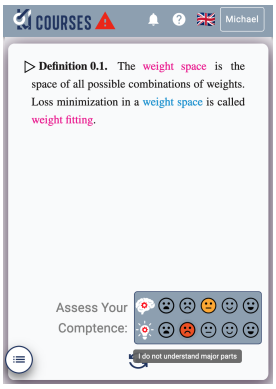
The dialogue planner assembles learning objects into active course material using

- ▷ 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

We can use the same four models discussed in the space of guided tours to deploy additional learning support services, which we now discuss.

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)

We have already seen above how the learner model can drive the drilling with flashcards. It can also be used for the configuration of card stacks by configuring a domain e.g. a section in the course materials and a competency threshold. We now come to a very important issue that we always face when we do AI systems that interface with humans. Most web technology companies that take one the approach "the user pays for the services with their personal data, which is sold on" or integrate advertising for renumeration. Both are not acceptable in university setting.

But abstaining from monetizing personal data still leaves the problem how to protect it from intentional or accidental misuse. Even though the GDPR has quite extensive exceptions for research, the ALeA system – a research prototype – adheres to the principles and mandates of the GDPR. In particular it makes sure that personal data of the learners is only used in learning support services directly or indirectly initiated by the learners themselves.

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!

▷ **Problem:** Learner model data is highly sensitive personal data!

▷ **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.

So, now that you have an overview over what the ALeA system can do for you, let us see what you have to concretely do to be able to use it.

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)
- **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)

Even if you did not understand some of the AI jargon or the underlying methods (yet), you should be good to go for using the ALeA system in your day-to-day work.

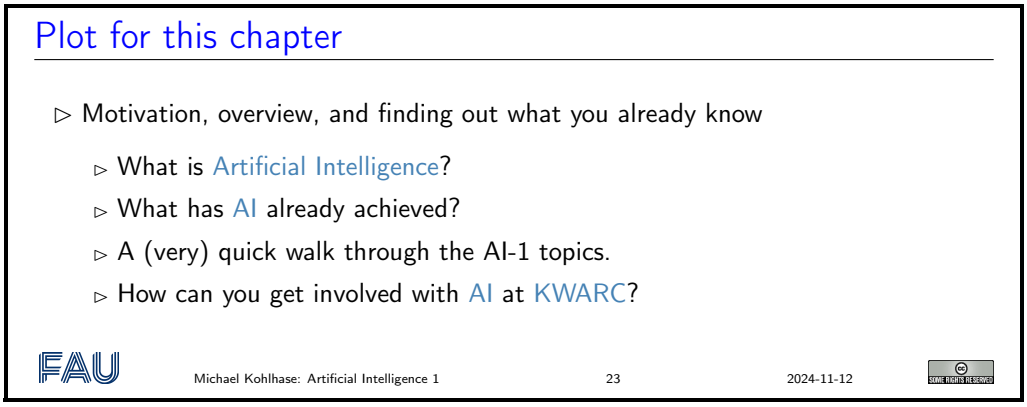
Chapter 2

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

We start the course by giving an overview of (the problems, methods, and issues of) Artificial Intelligence, and what has been achieved so far.

Naturally, this will dwell mostly on philosophical aspects – we will try to understand what the important issues might be and what questions we should even be asking. What the most important avenues of attacks may be and where AI research is being carried out.

In particular the discussion will be very non-technical – we have very little basis to discuss technicalities yet. But stay with me, this will drastically change very soon. **A Video Nugget** covering the introduction of this chapter can be found at `https://fau.tv/clip/id/21467`.



2.1 What is Artificial Intelligence?

A Video Nugget covering this section can be found at `https://fau.tv/clip/id/21701`.

The first question we have to ask ourselves is "What is Artificial Intelligence?", i.e. how can we define it. And already that poses a problem since the natural definition *like human intelligence, but artificially realized* presupposes a definition of intelligence, which is equally problematic; even Psychologists and Philosophers – the subjects nominally "in charge" of natural intelligence – have problems defining it, as witnessed by the plethora of theories e.g. found at [WHI].

▷ **Definition 2.1.1 (According to Wikipedia).** Artificial Intelligence (AI) is intelligence exhibited by machines

▷ **Definition 2.1.2 (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 2.1.3 (Elaine Rich).** Artificial Intelligence (AI) studies how we can make the computer do things that humans can still do better at the moment.

Maybe we can get around the problems of defining "what artificial intelligence is", by just describing the necessary components of AI (and how they interact). Let's have a try to see whether that is more informative.

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.

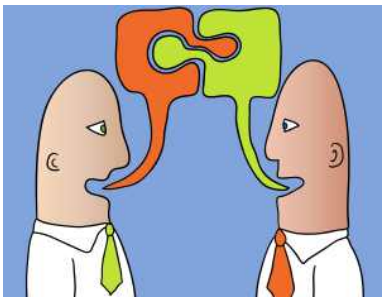
▷ This needs a combination of

the ability to learn

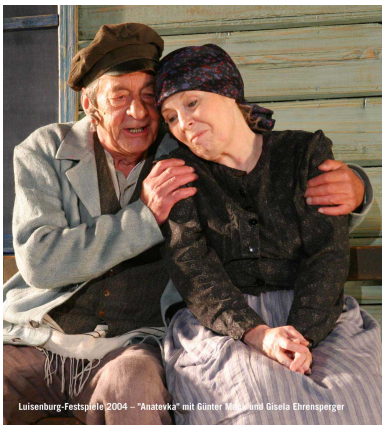
Inference

Perception

Language understanding



Emotion

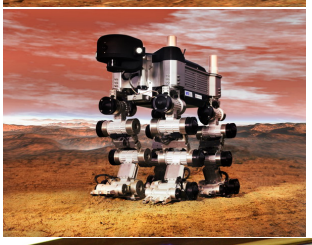


Note that list of components is controversial as well. Some say that it lumps together cognitive capacities that should be distinguished or forgets others, ... We state it here much more to get AI-1 students to think about the issues than to make it normative.

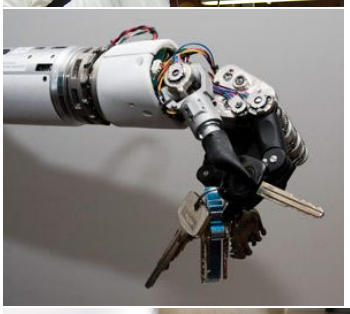
2.2 Artificial Intelligence is here today!

A Video Nugget covering this section can be found at `https://fau.tv/clip/id/21697`.
The components of Artificial Intelligence are quite daunting, and none of them are fully understood, much less achieved artificially. But for some tasks we can get by with much less. And indeed that is what the field of Artificial Intelligence does in practice – but keeps the lofty ideal around. This practice of "trying to achieve AI in selected and restricted domains" (cf. the discussion starting with slide 32) has borne rich fruits: systems that meet or exceed human capabilities in such areas. Such systems are in common use in many domains of application.

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
  - ▹ the user controls the prosthesis via existing nerves, can e.g. grip a sheet of paper.

- ▷ 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
  - ▹ in the USA 90% of the prostate operations are carried out by RoboDoc
  - ▹ Paro is a cuddly robot that eases solitude in nursing homes.

We will conclude this section with a note of caution.

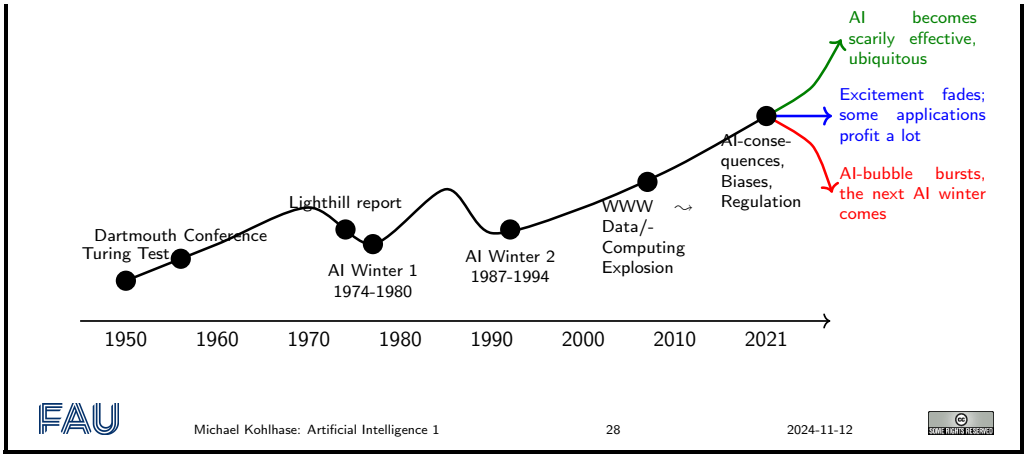
The AI Conundrum

- ▷ **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 2.2.1.** Functional/Logic Programming, automated theorem proving, Planning, machine learning, Knowledge Representation, ...
- ▷ **Still Consequence:** AI research was alternatingly flooded with money and cut off brutally.

All of these phenomena can be seen in the growth of AI as an academic discipline over the course of its now over 70 year long history.

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 2.2.2.** 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)



Of course, the future of AI is still unclear, we are currently in a massive hype caused by the advent of deep neural networks being trained on all the data of the Internet, using the computational power of huge compute farms owned by an oligopoly of massive technology companies – we are definitely in an AI summer.

But AI as a academic community and the tech industry also make outrageous promises, and the media pick it up and distort it out of proportion, ... So public opinion could flip again, sending AI into the next winter.

2.3 Ways to Attack the AI Problem

A Video Nugget covering this section can be found at `https://fau.tv/clip/id/21717`.
There are currently three main avenues of attack to the problem of building artificially intelligent systems. The (historically) first is based on the symbolic representation of knowledge about the world and uses inference-based methods to derive new knowledge on which to base action decisions. The second uses statistical methods to deal with uncertainty about the world state and learning methods to derive new (uncertain) world assumptions to act on.

Four Main Approaches to Artificial Intelligence

▷ **Definition 2.3.1.** 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.

▷ **Definition 2.3.2.** 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 2.3.3.** 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 2.3.4.** 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.

As a consequence, the field of Artificial Intelligence (AI) is an engineering field at the intersection of computer science (logic, programming, applied statistics), cognitive science (psychology, neuroscience), philosophy (can machines think, what does that mean?), linguistics (natural language understanding), and mechatronics (robot hardware, sensors).
Subsymbolic AI and in particular machine learning is currently hyped to such an extent, that many people take it to be synonymous with "Artificial Intelligence". It is one of the goals of this course to show students that this is a very impoverished view.

Two ways of reaching Artificial Intelligence?

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

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

▷ **This semester** we will cover foundational aspects of symbolic AI (deep/narrow processing)

▷ **next semester** concentrate on statistical/subsymbolic AI. (shallow/wide-coverage)

We combine the topics in this way in this course, not only because this reproduces the historical development but also as the methods of statistical and subsymbolic AI share a common basis.
It is important to notice that all approaches to AI have their application domains and strong points. We will now see that exactly the two areas, where symbolic AI and statistical/subsymbolic AI have their respective fortes correspond to natural application areas.

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 [**Ranta:atcp17**].

▷ **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.

An example of a producer task – indeed this is where the name comes from – is the case of a machine tool manufacturer T, which produces digitally programmed machine tools worth multiple million Euro and sells them into dozens of countries. Thus T must also comprehensive machine operation manuals, a non-trivial undertaking, since no two machines are identical and they must be translated into many languages, leading to hundreds of documents. As those manual share a lot of semantic content, their management should be supported by AI techniques. It is critical that these methods maintain a high precision, operation errors can easily lead to very costly machine damage and loss of production. On the other hand, the domain of these manuals is quite restricted. A machine tool has a couple of hundred components only that can be described by a comple of thousand attribute only.

Indeed companies like T employ high-precision AI techniques like the ones we will cover in this course successfully; they are just not so much in the public eye as the consumer tasks.

2.4 Strong vs. Weak AI

A Video Nugget covering this section can be found at `https://fau.tv/clip/id/21724`.
To get this out of the way before we begin: We now come to a distinction that is often muddled in popular discussions about "Artificial Intelligence", but should be cristal clear to students of the course AI-1 – after all, you are upcoming "AI-specialists".

Strong AI vs. Narrow AI

▷ **Definition 2.4.1.** 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 2.4.2.** 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 2.4.3.** 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!

One can usually defuse public worries about "is AI going to take control over the world" by just explaining the difference between strong AI and weak AI clearly.
I would like to add a few words on AGI, that – if you adopt them; they are not universally accepted – will strengthen the arguments differentiating between strong and weak AI.

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 2.4.4.** You should not train to be an accountant or truck driver!
(bots will replace you soon)

I want to conclude this section with an overview over the recent protagonists – both personal and institutional – of AGI.

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

A Video Nugget covering this section can be found at `https://fau.tv/clip/id/21719`.

We will now preview the topics covered by the course "Artificial Intelligence" in the next two semesters.

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

AI1SysProj: A Systems/Project Supplement to AI-1

- ▷ The AI-1 course concentrates on concepts, theory, and algorithms of symbolic AI.
- ▷ **Problem:** Engineering/Systems Aspects of AI are very important as well.
- ▷ **Partial Solution:** Getting your hands dirty in the homeworks and the Kalah Challenge
- ▷ **Full Solution:** AI1SysProj: AI-1 Systems Project (10 ECTS, 30-50places)
  - ▷ For each Topic of AI-1, where will be a mini-project in AI1SysProj
  - ▷ e.g. for game-play there will be Chinese Checkers (more difficult than Kalah)
  - ▷ e.g. for CSP we will schedule TechFak courses or exams (from real data)
  - ▷ solve challenges by implementing the AI-1 algorithms or use SoA systems
- ▷ **Question:** Should I take AI1SysProj in my first semester? (i.e. now)
- ▷ **Answer:** It depends . . . (on your situation)
  - ▷ most master's programs require a 10-ECTS "Master's Project"(Master AI: two)
  - ▷ there will be a great pressure on project places (so reserve one early)
  - ▷ BUT 10 ECTS $\widehat{=}$ 250-300 hours involvement by definition (1/3 of your time/ECTS)
- ▷ **BTW:** There will also be an AI2SysProj next semester! (another chance)

2.6 AI in the KWARC Group

A Video Nugget covering this section can be found at `https://fau.tv/clip/id/21725`.

Now allow me to beat my own drum. In my research group at FAU, we do research on a particular kind of Artificial Intelligence: logic, language, and information. This may not be the most fashionable or well-hyped area in AI, but it is challenging, well-respected, and – most importantly – fun.

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 ≙ 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

Research in the KWARC group ranges over a variety of topics, which range from foundations of mathematics to relatively applied web information systems. I will try to organize them into three pillars here.

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 ⇝ 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

For all of these areas, we are looking for bright and motivated students to work with us. This can take various forms, theses, internships, and paid students assistantships.

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, $(\text{Meta})^n$-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)

Sciences like physics or geology, and engineering need high-powered equipment to perform measurements or experiments. computer science and in particular the KWARC group needs high powered human brains to build systems and conduct thought experiments.

The KWARC group may not always have as much funding as other AI research groups, but we are very dedicated to give the best possible research guidance to the students we supervise.

So if this appeals to you, please come by and talk to us.

Bibliography

[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.

[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/.

[WHI] *Human intelligence — Wikipedia The Free Encyclopedia*. URL: https://en.wikipedia.org/w/index.php?title=Human_intelligence (visited on 04/09/2018).