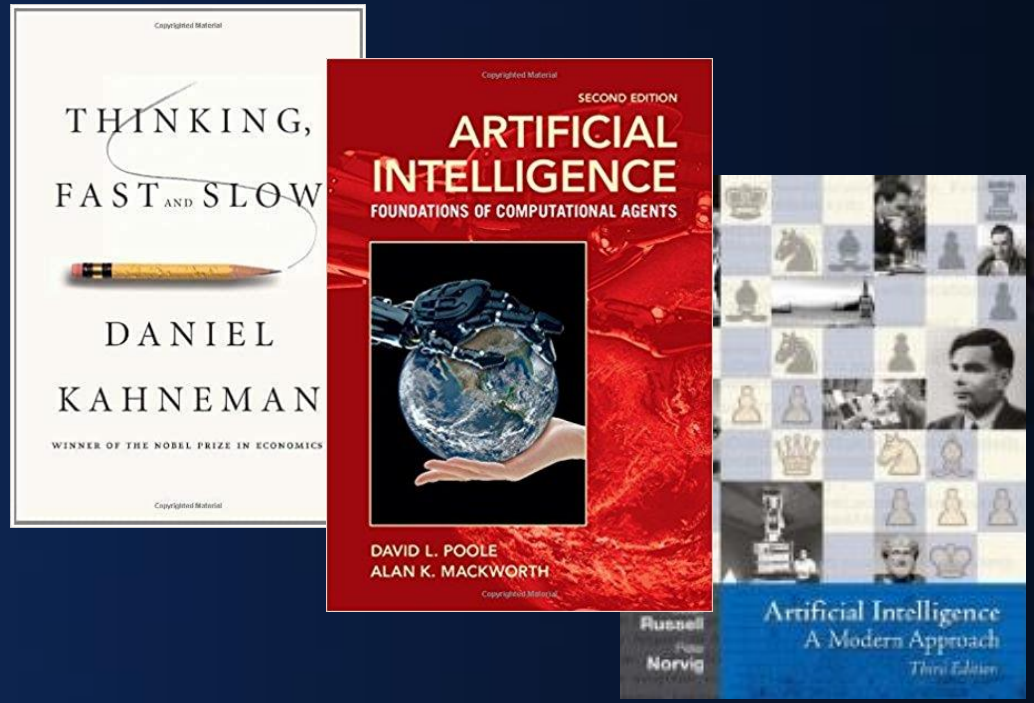

AI Fundamentals: an introduction

Slides originally crafted by Maria Simi, edited by V. Lomonaco

IN SUPREMÆ DIGNITATIS
1343

- CS BS @ UniMO, MS & PhD @ UniBO, Researcher @ UniPI
- Research focus: AI, Machine Learning, *Deep Continual Learning*
- President of *ContinualAI*
- Board Member of *AIforPeople*
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About your Instructor

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Course Main References

- **Course website**: https://elearning.di.unipi.it/course/view.php?id=498 (Guest access password: «aif2324»), you can **self-enroll** with your student credentials with the same password!
- **Reference book**: Artificial Intelligence: A Modern Approach, 4th US ed. Russel & Norvig, 2022.

We may regard the present state of the universe as the effect of the past and the cause of the future. An intellect which at any given moment knew all of the forces that animate nature and the mutual positions of the beings that compose it, if this intellect were vast enough to submit the data to analysis, could condense into a single formula the movement of the greatest bodies of the universe and that of the lightest atom; for such an intellect nothing could be uncertain and the future just like the past would be present before its eyes.

— Pierre Simon Laplace, A Philosophical Essay on Probabilities

AI Fundamentals: context

AI CURRICULUM

What about you? ☺

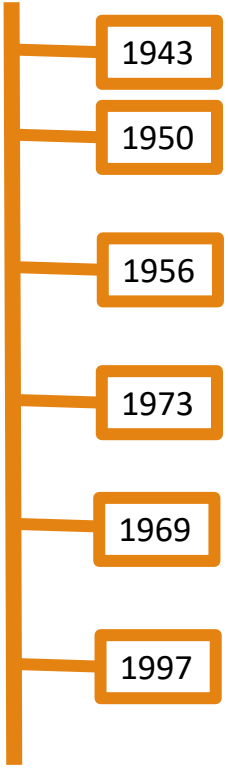
Summary

- The AI revolution and how we got here
- Deep learning and AI
- Thinking fast and slow
- The role of AIF in the AI curriculum
- Symbolic AI and the physical symbol system hypothesis
- «AI fundamentals» course at a glance
- Necessary background
- Methodology and evaluation

AI is taking over the world

Credit: Vincenzo Gervasi

AI timeline: milestones



1943 Mc Culloch & Pitts: first work on neural networks

1950 Turing test

1956 The birth of Artificial Intelligence (Dartmouth college)

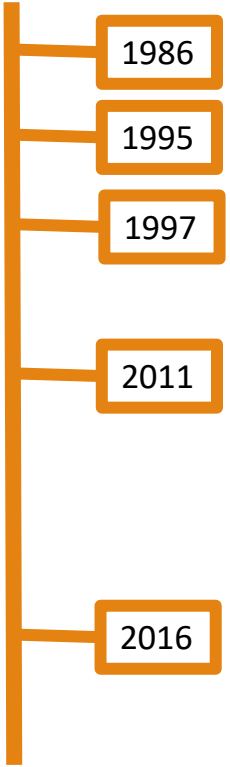
Theorem proving (Newell & Simon), games … symbolic reasoning

1973 The AI winter. The Lighhill report in UK -> *"In no part of the field have the discoveries made so far produced the major impact that was then promised".*

1969 The expert systems era begins … industrial applications

1997 Deep Blue defeats world chess champion G. Kasparov

AI timeline: milestones (cnt.)



1986 CYC (from “Cycorp”): commonsense knowledge

1995 Intelligent agents. AI: a modern approach.

1997 The RoboCup challenge. RoboCup rescue.

2011 The AI revolution begins … (*AI is all around us*, Wired).
Watson defeats human champion at Jeopardy!
The era of deep learning starts …

2016 DeepMind (Google) masters Go …

The deep learning tsunami

Deep Learning waves have lapped at the shores of computational linguistics for several years now, but 2015 seems like the year when the full force of the tsunami hit the major Natural Language Processing (NLP) conferences. [C. Manning]

Previous successes in the fields of image classification and speech …

Top experts in the field (LeCun, Hinton, Bengio) underline that there will be important developments in text and video understanding, machine translation, question answering … [Turing award 2019]

Google masters GO: *Deep-learning software defeats human professional for the first time*. AlphaGo. Nature 529, 445–446 (28 January 2016). In March 2016, Lee Sedol defeated by AlphaGo. [Nature 2016]

In 2017 AlphaGo-Zero learns to play “from scratch”, just by playing against itself.

Recent milestones

1. GPT3 (Generative Pre-trained Transformer), produced by OpenAI
   - May 2020: a larger and richer language model
   - 175 billion machine learning parameters
   - used for automatic text generation, translation, user interface synthesis
   - syntactically correct, very imaginative, … not necessarily true [News1, Video]
2. DARPA challenge (AlphaDogFights) with simulated F-16 Air Fighters
   - August 18-20 2020: Final event.
   - Eight AI system against each other; the winner was a system by Heron Systems
   - The Heron's system defeated a human expert top gun fighter 5-0!!!
   - Deep reinforcement learning [News]

Is Deep Learning the final solution to A.I.?

Andrew Ng

- Founder of the Google Brain team.
- Former director of the Stanford Artificial Intelligence Laboratory and professor
- Lead of Baidu's AI (1,200 people)
- Has directed many of the world's leading AI groups and built many AI products that are used by hundreds of millions of people

His answer:

1. *AI will transform many industries. But it's not magic*.
2. *Almost all of AI's recent progress is based on one type of AI, in which some input data (A) is used to quickly generate some simple response* (B) [A → B]

[https://hbr.org/2016/11/what-artificial-intelligence-can-and-cant-do-right-now]

What Machine Learning Can Do

A simple way to think about supervised learning.

INPUT A	RESPONSE B	APPLICATION
Picture	Are there human faces? (0 or 1)	Photo tagging
Loan application	Will they repay the loan? (0 or 1)	Loan approvals
Ad plus user information	Will user click on ad? (0 or 1)	Targeted online ads
Audio clip	Transcript of audio clip	Speech recognition
English sentence	French sentence	Language translation
Sensors from hard disk, plane engine, etc.	Is it about to fail?	Preventive maintenance
Car camera and other sensors	Position of other cars	Self-driving cars

SOURCE ANDREW NG

What *this* AI can do

- Supervised learning Achilles' heel: it requires a huge amount of data.

  building a photo tagger requires anywhere from tens to hundreds of thousands of pictures (A) as well as labels or tags telling you if there are people in them (B)

- *AI work requires carefully choosing A and B and providing the necessary data to help the AI figure out the A→B relationship*.

- So what is the potential of implementing the mapping A→B?

  Ng's rule of tumb:

  If a typical person can do a mental task with less than one second of thought, we can probably automate it using AI either now or in the near future.

  Choosing A and B creatively has already revolutionized many industries. It is poised to revolutionize many more.

Issues for effective use of AI

Software. Not a problem: the community is quite open. *Among leading AI teams, many can likely replicate others' software in, at most, 1–2 years ...*

Data. … *But it is exceedingly difficult to get access to someone else's data. Thus data, rather than software, is the defensible barrier for many businesses.*

Talent. *Simply downloading and "applying" open-source software to your data won't work. AI needs to be customized to your business context and data. This is why there is currently a war for the scarce AI talent that can do this work.*

I would add to this …

Computational resources.

Deep learning and AI

- *Deep learning* is only one approach inside the much wider field of *machine learning* and …
- *Machine learning* is one approach within the wider field of AI
- Ng: *Many researchers are exploring other forms of AI, some of which have proved useful in limited contexts; there may well be a breakthrough that makes higher levels of intelligence possible, but there is still no clear path yet to this goal*

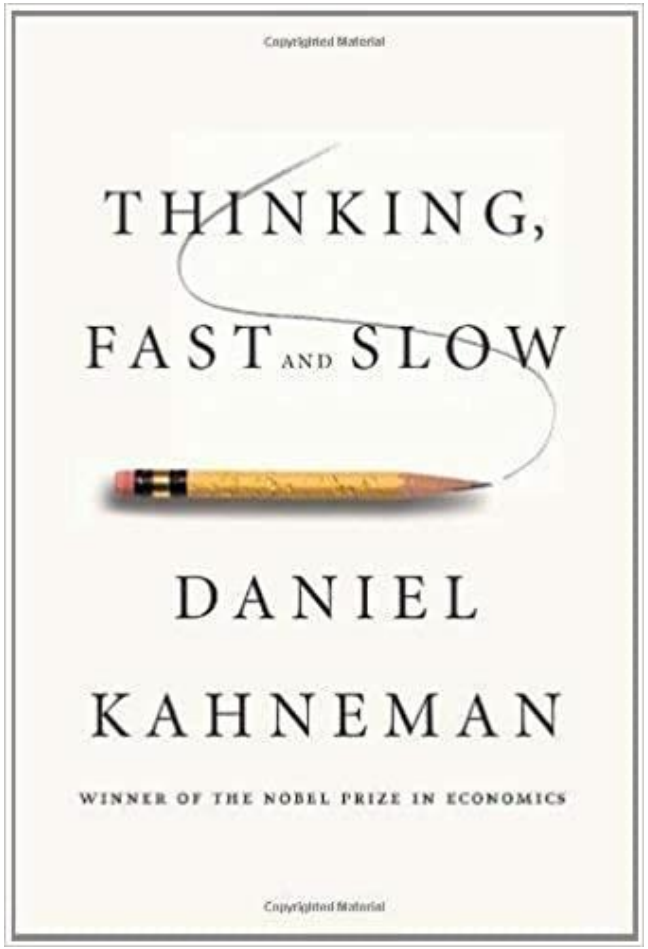
- Thinking fast and slow …

Thinking fast and slow

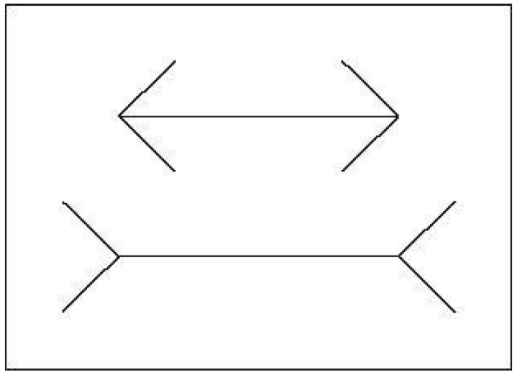
- Daniel Kahneman, 2011
- Recipient of Nobel Prize for Economics in 2002
- System1/System2 distinction.

  Two systems/agents in the brain to account for
  - perception and intuition (fast thinking)
  - complex reasoning (slow thinking)

  …



System 1



System 2

Task: compute 17 x 24

1. Could it be 12609?
2. Could it be 123?
3. Could it be 568?

System 1

- Perceptual tasks
- Simple computations
- Understanding simple sentences
- Tasks that become mechanical by training and do not require attention
- For experts is different

System 2

- Tasks that require attention and conscious effort
- Complex computations
- Recalling from memory
- Complex logical argumentation
- Reasoned justifications
- Controlling instinctual reactions

Selective attention test

1. https://www.youtube.com/watch?v=vJG698U2Mvo

A test to demonstrate that certain tasks absorb your mental faculties.

A variant:

2. https://www.youtube.com/watch?v=IGQmdoK_ZfY

Is A.I. all about Machine Learning?

Possible arguments against **ML** in some applications:

1. Explanation and accountability: ML systems are not (yet?) able to justify in human terms their results. For some application it is essential.
   - Knowledge must be meaningful to humans to be able to generate explanations?
   - Some regulations requires the **right to an explanation** in decision-making, and seek to **prevent discrimination** based on race, opinions, health, sex … (e.g. GDPR)
   - AI for decision support for humans? Yes, but …
2. ML systems learn what's in the data, *without understanding what's true or false, real or imaginary, fair or unfair*
   - Most popular opinion in the training data; possible to develop **bad/unfair** models
   - People are generally more critical about information

My intermediate conclusions

1. The goal of building AI systems is far from being solved and is still quite challenging in its own.
2. Building complex AI systems requires the combination of several techniques and approaches, not only ML.
3. One of the most challenging tasks ahead of us is integration of perception and reasoning in AI systems

In this course you'll develop a more comprehensive skillset, ***a toolbox to build intelligent agents****, regardless of the methodological approach and task to solve!*

AI Fundamentals

AI fundamentals is mostly about “Slow thinking” or “Reasoning”

AI fundamentals has the role, within the AI curriculum, of teaching you about the foundations of a discipline which is now 60 year old.

We will cover different approaches, also coming of the “Good Old-Fashioned Artificial Intelligence” (GOFAI) or “symbolic AI”.

Symbolic AI

High-level "symbolic" (human-readable) representations of problems, the general paradigm of **searching** for a solution, knowledge representation and reasoning, planning.

Symbolic AI was the dominant paradigm of AI research from the mid-1950s until the late 1980s.

Central to the building of AI systems is the **Physical symbol systems hypothesis**, formulated by Newell and Simon.

[*Computer Science as Empirical Inquiry: Symbols and Search, Newell&Simon*]

Physical symbol systems hypothesis (PSSH)

The approach is based on the assumption that many aspects of intelligence can be achieved by the manipulation of symbols (the **physical symbol system hypothesis)**:

> "*A physical symbol system has the **necessary and sufficient** means for general intelligent action*" [Allen Newell, Herbert A. Simon]

1. Human thinking is a kind of symbol manipulation system (a symbol system is **necessary** for intelligence).
2. Machines can be intelligent (a symbol system is **sufficient** for intelligence)

The hypothesis cannot be proven, we can only collect empirical evidence.

1. Observations and experiments on human behavior in tasks requiring intelligence. Computational models.
2. Solving tasks of increasing complexity.

Strong versus weak AI

The Chinese room argument by John Searle [https://www.britannica.com/biography/John-Searle/Philosophy-of-mind]

Video

Searle introduced the following distinction:

- **Strong AI** relies on the *strong* assumption that human intelligence can be reproduced in all its aspects (general A.I.). It includes adaptivity, learning, consciousness … not only pre-programmed behavior.
- **Weak AI**: simulation of human-like behavior, without effective thinking/understanding; no claim that it works like human mind. The dominant approach today.

Challenges to PSSH and to strong AI

Robot says: Whatever (Margaret Boden)

What stands in the way of all-powerful AI isn't a lack of smarts: it's that computers can't have needs, cravings or desires

Abraham Maslow's 'hierarchy of [human] needs':

1. Biological needs (food, sleep, sex, …)
2. Safety, protection from environment
3. Love and belonging, friendship
4. Self esteem and respect from others
5. Self-actualization

https://aeon.co/amp/essays/the-robots-wont-take-over-because-they-couldnt-care-less

The AI curriculum

AI curriculum: structure

	CFU
Curriculum specific courses (mandatory)	**45**
Artificial Intelligence Fundamentals (sem 1)	6
Machine Learning (sem 1)	9
Computational mathematics for learning and data analysis (sem 1)	9
Natural Languages Technologies (sem 2)	9
Distributed systems: paradigms and models (sem 2)	9
Intelligent Systems for Pattern Recognition (sem 2)	6
Smart Applications (sem 3)	9
Electives	**30**
Free choice	**9**
Thesis	**24**
Total	**120**

AI curriculum: electives

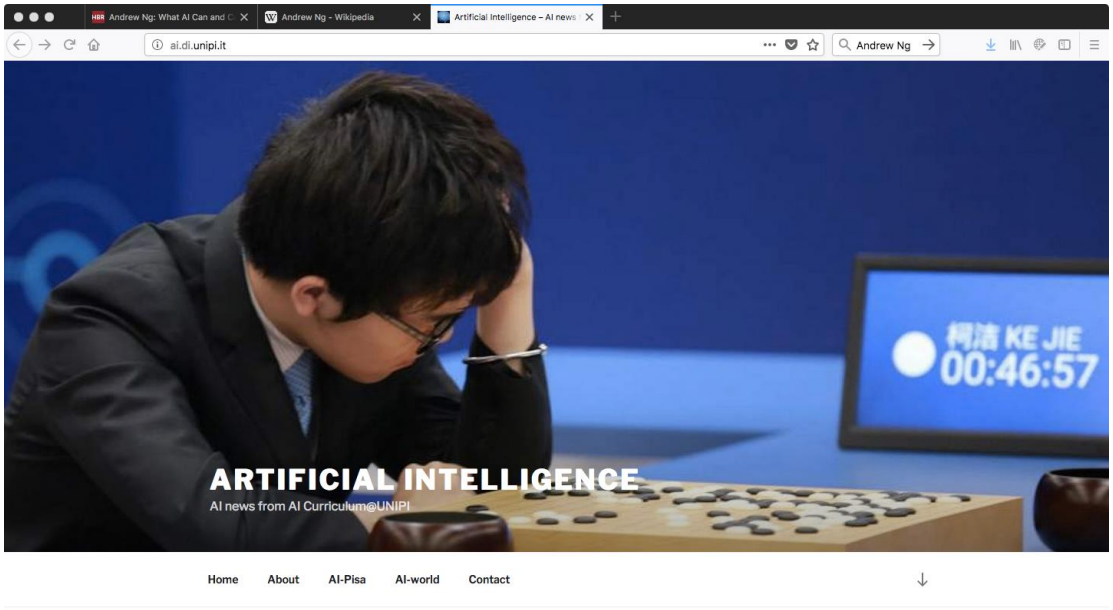
Curriculum electives	**30**
Algorithm engineering [from KD] (1 sem)	9
Data mining [from KD] (1 sem)	9
Mobile and cyber-physical systems [from ICT] (2 sem)	9
Information retrieval [from KD] (1 sem)	6
Computational neuroscience [from ING] (2 sem)	6
Social and ethical issues in computer technology (2 sem)	6
Robotics [S. Anna] (2 sem)	6
Semantic web [CNR] (1 sem)	6
Computational Models for Complex Systems (2 sem)	6
Free choice	9
Total	**39**

AI curriculum: more electives

Some more electives	**30**
Algorithmic Game Theory	6
Laboratory on ICT Startup Building	6
Introduction to Quantum Computing	6
Computational Health Laboratory	6
Continual learning	6
3D Geometric Modeling & Processing	6

The blog of the AI curriculum

http://ai.di.unipi.it



AI Fundamentals at glance

THE STRUCTURE OF THE COURSE

TEACHING METHODOLOGY

The main topics

Prerequisites: algorithms, logic, programming, basic probability.

The course **will not assume** an introduction to AI as a prerequisite.

I - Introduction to the Course and AI (3)

II - Problem Solving (5)

III - Knowledge, Reasoning, and Planning (6)

IV - Uncertain Knowledge and Reasoning (6)

V - On the Future of AI (4)

Total: 24 (48 hours)

I - Introduction to the Course and AI

1. Intro to the course
2. Rational Agents architecture
3. Projects proposal and evaluation details

II - Problem Solving

1. Solving Problems by Searching
2. Search in Complex Environments
3. Constraint Satisfaction Problems
4. Adversarial Search and Games
5. Hands-on session

III – Knowledge, Reasoning, and Planning

1. Logical Agents
2. First-Order Logic
3. Inference in First-Order Logic
4. Knowledge Representation
5. Automated Planning
6. Hands-on session with Prolog

IV - Uncertain Knowledge and Reasoning

1. Quantifying Uncertainty
2. Probabilistic Reasoning
3. Probabilistic Reasoning over Time
4. Multi-Agent Decision Making
5. Probabilistic Programming
6. Hands-on Session

V - On the Future of AI

1. Philosophy, Ethics and Safety and the Future of AI
2. Projects Presentation (1)
3. Projects Presentation (2)
4. Invited Seminar on Advanced AI topics

Main books for the course

[AIMA] Stuart J. Russell and Peter Norvig. *Artificial Intelligence: A Modern Approach* (4th edition). Pearson Education, 2022.

[AI-FCA] David L. Poole, Alan K. Mackworth. *Artificial Intelligence: foundations of computational agents*, Cambridge University Press, 2017. http://artint.info/2e/html/ArtInt2e.html (online version)

[KR&R] Ronald Brachman and Hector Levesque. *Knowledge Representation and Reasoning*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA. 2004.

[AI-LF] Genesereth, M., and Nilsson, N., Logical Foundations of Artificial Intelligence, San Francisco: Morgan Kaufmann, 1987.

[AI-NS] Nils Nilsson, N., *Artificial Intelligence: A New Synthesis*, San Francisco: Morgan Kaufmann, 1998.

Course vs Curriculum vs AIMA

Preface (pdf): Contents with subsections

I Artificial Intelligence
1 Introduction ... 1
2 Intelligent Agents ... 36

II Problem-solving
3 Solving Problems by Searching ... 63
4 Search in Complex Environments ... 110
5 Adversarial Search and Games ... 146
6 Constraint Satisfaction Problems ... 180

III Knowledge, reasoning, and planning
7 Logical Agents ... 208
8 First-Order Logic ... 251
9 Inference in First-Order Logic ... 280
10 Knowledge Representation ... 314
11 Automated Planning ... 344

IV Uncertain knowledge and reasoning
12 Quantifying Uncertainty ... 385
13 Probabilistic Reasoning ... 412
14 Probabilistic Reasoning over Time ... 461
15 Probabilistic Programming ... 500
16 Making Simple Decisions ... 528
17 Making Complex Decisions ... 562
18 Multiagent Decision Making ... 599

V Machine Learning
19 Learning from Examples ... 651
20 Learning Probabilistic Models ... 721
21 Deep Learning ... 750
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VI Communicating, perceiving, and acting
23 Natural Language Processing ... 823
24 Deep Learning for Natural Language Processing ... 856
25 Computer Vision ... 881
26 Robotics ... 925

VII Conclusions
27 Philosophy, Ethics, and Safety of AI ... 981
28 The Future of AI ... 1012
Appendix A: Mathematical Background ... 1023
Appendix B: Notes on Languages and Algorithms ... 1030
Bibliography ... 1033 (pdf and LaTeX .bib file and bib data)
Index ... 1069 (pdf)

Exercises (website)
Figures (pdf)
Code (website); Pseudocode (pdf)
Covers: US, Global

ML, ISPR, Comp. Neuro

Robotics, ISPR, NLP, etc.

Social and ethical issues in computer technology

Game Theory, Parallel & Distrib Sys.

AI Fundamentals: necessary background

WHAT YOU NEED TO KNOW

HOW TO FILL THE GAPS

Prerequisites

- Expected background from computer science (*recover it now!!*)
  - ✓ Algorithms and complexity
  - ✓ Formal logic
  - ✓ Computability
  - ✓ Elements of probability calculus
- A basic course in Artificial Intelligence (useful)
  - ✓ Problem solving as search
  - ✓ Representation and reasoning in classical logic

Evaluation

- Team Projects (more details in the 3rd lecture) -> **1/3**
  - in-class presentation
  - computational notebook report
- Team oral (project intro + 3 questions each) -> **2/3**

Suggested Book and Movies

1. Book to know like your holy bible:
   - "Artificial Intelligence: A Modern Approach", 4th US ed. Russel & Norvig, 2022.

2. Suggested Books to read:
   - "Thinking fast and slow", Daniel Kahneman, 2011.
   - "The Singularity Is Near", R. Kurzweil, 2005.
   - "Runaround", I. Asimov, 1942.
   - "On Intelligence", Jeff Hawkins, 2004.
   - "Superintelligence: Paths, Dangers, Strategies", Nick Bostrom, 2014.
   - "Rebooting AI: Building Artificial Intelligence We Can Trust", Ernest Davis and Gary Marcus, 2019.

3. Suggested Movies to watch:
   - ✓ "2001: Space Odyssey", Stanley Kubrick, 1968.
   - ✓ "A.I. Artificial Intelligence", Steven Spielberg, 2001.
   - ✓ "The Matrix", Lana Wachowski & Lilly Wachowski, 1999.
   - ✓ "Ex Machina", Alex Garland, 2015.
   - ✓ "Her", Spike Jonze, 2014.
   - ✓ "The Imitation game", Morten Tyldum, 2014.

Next

- AI means building **intelligent computational agents**
- Unified vision of the enterprise of building AI systems.
- We are only interested in their external behavior in terms of **actions**, whether they do the right thing or not.