Artificial Intelligence: Evolution & Perspectives

Digital Culture

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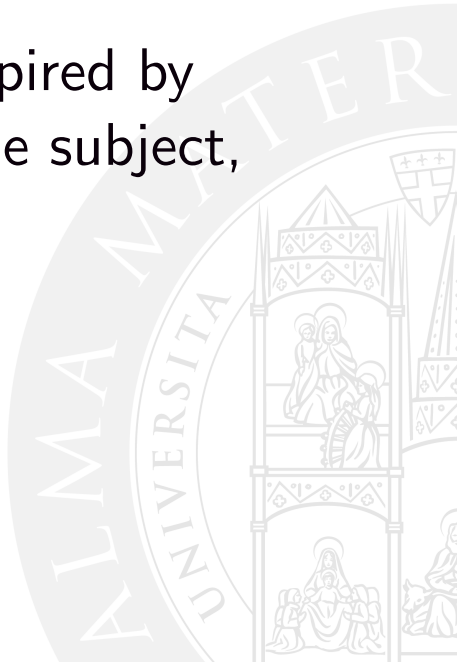
Academic Year 2018/2019

Disclaimer

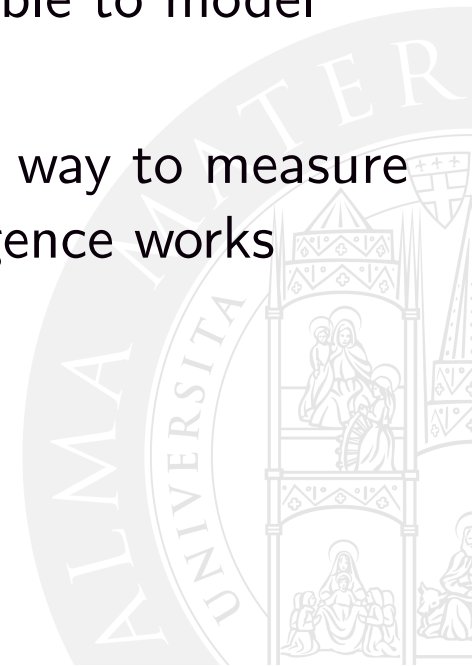
- a number of different sources were used to prepare these slides—including of course more than two decades of research in the field by myself
- however, the organisation of the material is largely inspired by [Wooldridge, 2018], which represents a fresh reading on the subject, indeed



Next in Line...

The Idea of Intelligence

- understanding how intelligence works is a persistent issue for humans
- Aristotle's logics is the most outstanding example of that
- "understanding", for humans, typically means to be able to model and reproduce
- building machines that can reproduce intelligence is a way to measure how much we do understand the way in which intelligence works



The Idea of Intelligent Machines

- humans as makers of machines exhibiting intelligent behaviours
- machines vs. humans—from The Turk to AlphaGo
- the basic question: what is intelligence, which we aim at capture and reproduce?

The Turing Test I

- after providing the fundamental theoretical machinery for computation (the Turing Machine [Turing, 1937]), Turing started exploring the limits of automatic computation: could it be a path towards intelligence of machines?
- the Turing Test [Turing, 1950]

  "You are interacting via a computer keyboard and screen with something that is either another person or a computer program. The interaction is in the form of text – questions and answers. Your task is to determine whether the thing being interrogated is in fact a person. Now suppose, after some time, you cannot tell whether the thing is a person or program. Then, Turing argued, you should accept that the thing being interrogated has human-like intelligence." *[Wooldridge, 2018]*

The Turing Test II

- *behavioural* interpretation of intelligence—independent from how it works, dependent on what it can achieve
- indistinguishable from human behaviour
- it has limitations, it has been refined, it is anyway meaningful

Against AI I

- many scientists have argued agains the chance of machine intelligence
- mostly philosophers, like Searle [Searle, 1980]

The Chinese Room

"Imagine a room in which a man, who understands no Chinese, receives, through a slot in the door, questions written in Chinese. When he receives a question, the man carefully follows detailed instructions written in English to generate a response to the question, which he passes back out through the slot. Now suppose the questions and responses are part of a Chinese Turing test, and the test is passed." [Wooldridge, 2018]

Against AI II

- interesting argument
- so many assumptions and mistakes in it
- which does not mean its conclusions are wrong, of course

Next in Line...

AI is Born in 1956

The Golden Age of AI

- Dartmouth College, New Hampshire, Summer School, 1956
- John McCarthy invites all scholars interested in computing towards intelligence
- among those
  - Marvin Minsky, co-founder of AI Lab at MIT
  - Alan Newell, Herb Simon, authors of Logic Theorist (an automatic theorem prover), likely the first AI program
  - John McCarthy, inventor of LISP, the first programming language for AI
- the term "Artificial Intelligence" was actually coined there, to describe the overall new field of research
- the dualism between AI as *intelligent behaviour* and AI as *intelligent process* already there, from the beginning

General AI I

General purpose AI

- building general-purpose intelligence machines is the goal of General AI
- we do have a poor understanding of human intelligence, and of intelligence in general
- early AI focussed then on *intelligent components*

General AI II

Components of intelligence

- perception
- machine learning
- problem solving & planning
- reasoning
- natural language understanding

Perception

- understanding the environment
- through sensors of any sort
- interpreting the overall situation
- ! one of the most difficult task of AI

General AI III

Machine learning

- learning from data
- building models (e.g., classification)
- making prediction
- e.g., face recognition through training

Problem solving & planning

- devising a course of actions towards a *goal*
- based on a *repertoire of actions*
- e.g., playing games

General AI IV

Reasoning

- inferring new knowledge from available one
- in a consistent and robust way

Natural language understanding

- ability to understand human languages
- either spoken or written
- possibly engage in conversations with humans

Next in Line...

Search

Searching for solution

- from the current state of the world to a desired one, called goal
- based on a repertoire of available *actions*
- modelled in terms of their
  - *pre-conditions*, or, the state of the world in which they can be applied
  - *effects*, or, the state of the world they bring about
- a *search tree* can be built
  - from the *initial state* as its root—*forward search*
  - from the *final state* as its root—*backward search*

The Problem of Search

Explosion of the space of solutions

- search trees become too large
- *combinatory explosion*
- e.g., game of chess
- possible approach: *heuristics* as rule of thumb to direct search and reduce computational complexity
- e.g., IBM's Deep Blue against Gary Kasparov in 1996, combining computational power with heuristics

Planning in the Block World

SHRDLU

- the Blocks World is a virtual environment where a number of coloured objects (blocks, boxes, pyramids) are arranged on a surface (a table)
- SHRDLU was aimed at arranging the objects following user's instructions
- using a simulated robot arm with heuristics
- it worked: both the user interaction via a sort of natural language, and the practical reasoning (reasoning towards action)
- limits: language and environment actually very simplistic, not representative of real world interaction

Robots

SHAKEY with STRIPS

- a remotely-controlled mobile robot
- moving objects in an office-like environment by pushing them
- planning with STRIPS
- it somehow worked
- limits: limited ability to perceive and understand real-world environment, so the environment had to be built around it to make SHAKEY work
- basically, it looked like a real-world robot, but never worked in the real world

Next in Line...

Complexity I

Microworld does no scale up to real-world

- solutions in microword apparently do not work in real world
- qualitative or quantitative issues?

NP-complete problems

- *Non-deterministic Polynomial time complete* (NP-complete) problems
  - easy to check correctness of solutions
  - almost impossibile to *find* a solution in a reasonable amount of time
  - e.g., Travelling Salesman Problem (TSP)

! almost all relevant problems in AI are (at least) NP-complete

Complexity II

AI Winter

- AI started with way too much hype
- e.g., General Problem Solver (GPS) never worked for real-world problems
- in a couples of decades, nothing was really accomplished

! Funding for AI research were cut everywhere, starting from the seventies

Tackling Complexity with Knowledge I

A way out

- humans do not explore enormous search spaces to find solutions
- they use (possibly extensive) *domain knowledge* to cut down the search space
- e.g., chess players

! the idea: exploiting explicit (domain) knowledge representation to make solutions computable

Tackling Complexity with Knowledge II

Expert systems

- a new class of AI systems emerged
  - no longer General AI, since they were tailored to specific domains
  - working only there
  - yet finally facing real-world problems successfully
- *expert systems* were built by
  - eliciting knowledge from domain experts
  - representing them in terms of *rules*
  - able to provide answers to human questions over a domain
  - along with an *explanation*
  - often coping with uncertainty

Tackling Complexity with Knowledge III

MYCIN

- nearly 200 rules
- about blood disease
- working as a doctor's assistant
- issues
  - difficult to extract knowledge from humans, and to precisely formalise it in terms of rules
  - operating only in a very narrow area of expertise

Tackling Complexity with Knowledge IV

CYC

- representing everything in the world in terms of rules
- an expert systems containing all the common sense human knowledge in terms of rules
- Doug Lenat's CYC started in 1984...
- ... and is still alive
- way too ambitious: some call it a failure
- yet it now lives out of its commercial applications

Computational Logic for AI

Logic Programming

- capturing knowledge, inferring new knowledge—with the precision and rigour of logic
- computing with logic: the PROLOG programming language [Colmerauer and Roussel, 1996]
  - knowledge and programs expressed in terms of *logic axioms* (Horn clauses)
  - altogether forming a *logic theory*
  - against which *goals* are demonstrated
  - *computation* as *goal demonstration* [Lloyd, 1984]
- issues
  - heavy computational load
  - not fitting (alone) real-world representation and computation

Bayesian reasoning

Coping with uncertainty

- humans are not good decision makers
- *rational decisions* better than human decisions in most fields, in particular where uncertain information is available
- e.g., when probabilistic reasoning is involved
- Bayes developed the math in the eighteen century, and a couple of centuries were required to make *Bayesian reasoning* usable for AI
- e.g., many NLP systems use Bayesian networks

Nouvelle AI

Against reasoning, against representation [Brooks, 1991a, Brooks, 1991b]

- frustration from absence of real-world results led to focus on real world itself
- against knowledge-based and logic-based AI
- perceive and react as the main cycle of robots in the real world, rather than (symbolic) reasoning

Behavioural AI

Robotics revolution [Brooks, 1986]

- focus on individual intelligent behaviours expected
- just build them, according to how they do relate with each other
- in particular, which ones take the precedence on the others
- e.g., Roomba vacuum cleaner

Next in Line...

Autonomous Vehicles

Grand DARPA Challenges

- race for autonomous vehicles in the desert of Nevada (2005)
- won by STANLEY, a converted Volkswagen Touareg, equipped with seven onboard computers, interpreting sensor data from GPS, laser rangefinders, radar, and video feed

Machine Learning I

Computer that learn

- machine learning (ML) aims at computers that learn knowledge they have not be explicitly told
- they are typically *trained*

Supervised learning

- training by examples of the thing that the computer is trying to learn—*training data*
- e.g, face recognition

Machine Learning II

Reinforcement learning

- a system is able to experiment by making decisions
- receives feedback on those decisions
- and learns from that

Three factor for the success of ML

- scientific breakthroughs—deep learning dealing with complex problems
- training requires a lot of data data—nowadays data are hugely available
- training requires computational power—nowadays computational power is more and more available

Neural Nets

Nets of neurons

- *neural nets* implement ML by connecting many artificial neurons in complex networks
- each neuron gets input from neighbours and produces an output based on some *weights*
- learning occurs by adjusting weights
- two-phase research
  - first, simple neural networks show potential and are proven to have limits
  - then, more complex networks were proven able to overcome these problems
- e.g., character recognition
- ! issue: opaque, no explanation made available—expertise hidden in weights

Triumph of ML

Alpha Go

- in 2014 DeepMind demonstrated a system learning how to play arcade games just looking at the video and accessing the scores, using the same controls as humans
- acquired by Google, they built Alpha Go, which beat Go champion Lee Sedol 4 to 1 in 2016
- exploiting *deep neural networks* along with *self-training*
- Go search space is so huge that brute force just does not work: so, it was considered impossible for a machine to beat a human
- so, this also made everybody know that there were no known limits to the ability that machine intelligent could reach

Next in Line...

AI Today

AI everywhere [Wooldridge, 2018]

- digital assistants like Siri, Alexa, and Cortana are classic AI
- face recognition software in social media is AI
- the software in car's satellite navigation system is AI
- product recommendations from online stores are made by AI
- cruise control systems in modern cars are AI
- AI-based automated translation systems are routinely used across the world
- ...

AI is just everywhere already

Challenges I

Challenges for society

- autonomous vehicles against millions of truck drivers
- conversational systems in contact centres
- intelligent machines will take many skilled roles
- what about unemployment?

AI is just everywhere already

ML vs. privacy

- ML can understand thing about us that are hidden in data, and invisible to humans
- a challenge for law-makers is to rule algorithms that have capabilities far beyond humans

Challenges II

Autonomous weapons

- a blessing or an unacceptable risk?
- more generally, *machine ethics* is nowadays a subject of scientific scrutiny

Fears of future AI

- singularity?
- conscious machines?

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