Artificial Intelligence & Machine Learning

A.Y. 2024/2025

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Introduction to AI&ML

What is AI?

AI is about devising *agents* (programs or devices) that act "Intelligently"

Blurry definition, informal

Several approaches, over time:

1. Turing test (1950): act as a human
   - Needs Knowledge Representation and Reasoning abilities (we have it!)
2. Cognitive modeling: think as a human
   - Do we really know how we think?
3. Think rationally: use rules of logic (e.g., Aristotle Syllogisms)
   - Needs formalization of logical reasoning (we have it!)
4. **Act rationally**: act so as to achieve best (expected) outcome
   - Prevailing approach to date, combines 1, 3 and additional abilities (e.g., autonomy, uncertainty)

What is AI, (a bit more) formally

Devising agents that behave so as to *maximize an objective function*

- Autonomous drive:
  - Reach destination safely and in shortest possible time
- Trading agent:
  - Make as much money as possible
- Chatbot:
  - Reply correctly to as many questions as possible
- E-commerce recommender system:
  - Recommend products so as to maximize number of customers who buy them
- …

And Machine Learning?

- Subarea of AI
- Grown so much that it is now studied separately
- Still about **acting rationally**, but:
  - behavior learned from examples (data), not built-in
  - no (primary) interest on internal details (why a decision was made?)

Inductive vs Deductive AI

Two approaches:

- *Deductive* (reasoning-based, ``traditional'' AI)
  - Start from general rules, facts, requirements, goals
  - Deduce new knowledge, sequence of actions, etc… through some form of reasoning
  - Includes probabilistic reasoning
  - Typically, ``exact'' methods

Part 1 (AI)

- *Inductive* (ML)
  - Start from collected data
  - Learn input-output relationship underlying data
  - Use learned laws for your purposes (classification, regression, generation, etc…)
  - System may need to generate data itself (e.g., Reinforcement-Learning)

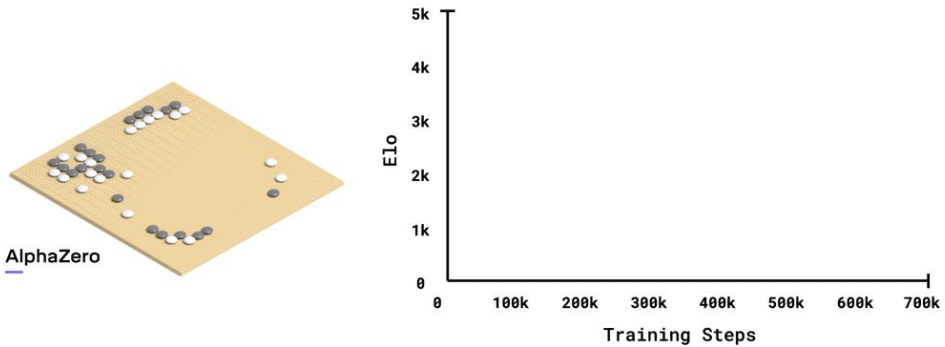
Part 2 (ML)

Modern AI systems typically combine the two!

Some Examples/1

AlphaZero:

- A World-Champion level algorithm for Go, Chess and Shogi (Japanese Chess)
- Combines probabilistic approach (MCTS) with ML (Reinforcement-Learning, Neural Nets)
- Self-taught by playing against itself

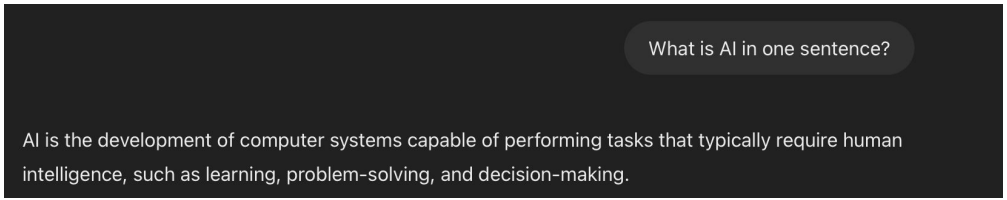


(courtesy of DeepMind https://deepmind.google/discover/blog/alphazero-shedding-new-light-on-chess-shogi-and-go/)

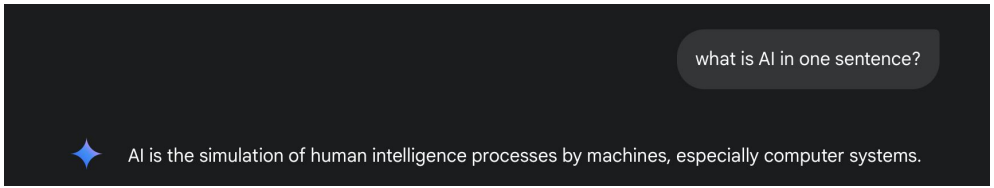
Some Examples/2

Chat GPT, Gemini:

- Large Language Models able to carry on a conversation
- Trained on data coming from several sources (Wikipedia, Book corpora, Forums,...)
- Combine various ML approaches (Supervised and Reinforcement Learning)



(courtesy of OpenAI chatgpt.com)



(courtesy of Google gemini.google.com)

Some Examples/3

NASA Planning, Scheduling and Resource Management tools

Mission Planning and Management

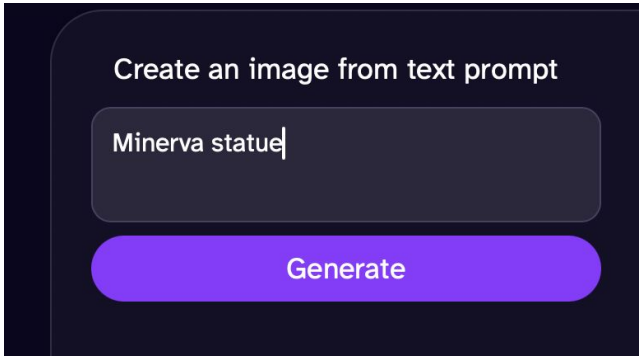
- ASPEN Mission Planner: AI-assisted tool that helps streamline space mission planning and scheduling, optimizing mission efficiency.
- AWARE (Autonomous Waiting Room Evaluation): AI system that manages operational delays, improving mission scheduling and resource allocation.
- CLASP (Coverage Planning & Scheduling): AI tools for resource allocation and scheduling, ensuring mission activities are executed seamlessly.
- Onboard Planner for Mars2020 Rover: AI system that helps the Perseverance Rover autonomously plan and schedule its tasks during its mission.

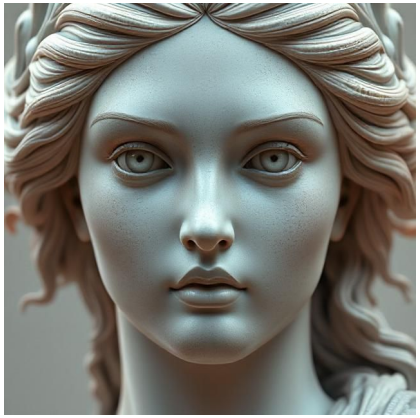
(courtesy of NASA https://deepmind.google/discover/blog/alphazero-shedding-new-light-on-chess-shogi-and-go/)

Some Examples/4

AI-generated Images
in different styles

(courtesy of DeepAI - deepai.org)





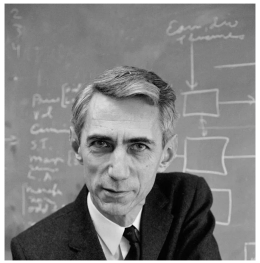
In this course

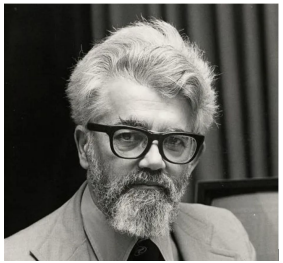
We shall see much simpler applications

By the end of the course, you'll be able to:

- Understand the basics of AI systems
- Develop simple AI systems based on basic forms of reasoning and learning
- Learn about advanced approaches of practical relevance

Official Birth of AI





Summer '56:

- Two-month workshop at Dartmouth College, Hanover (New Hampshire)
- Organized by John McCarthy and Claude Shannon

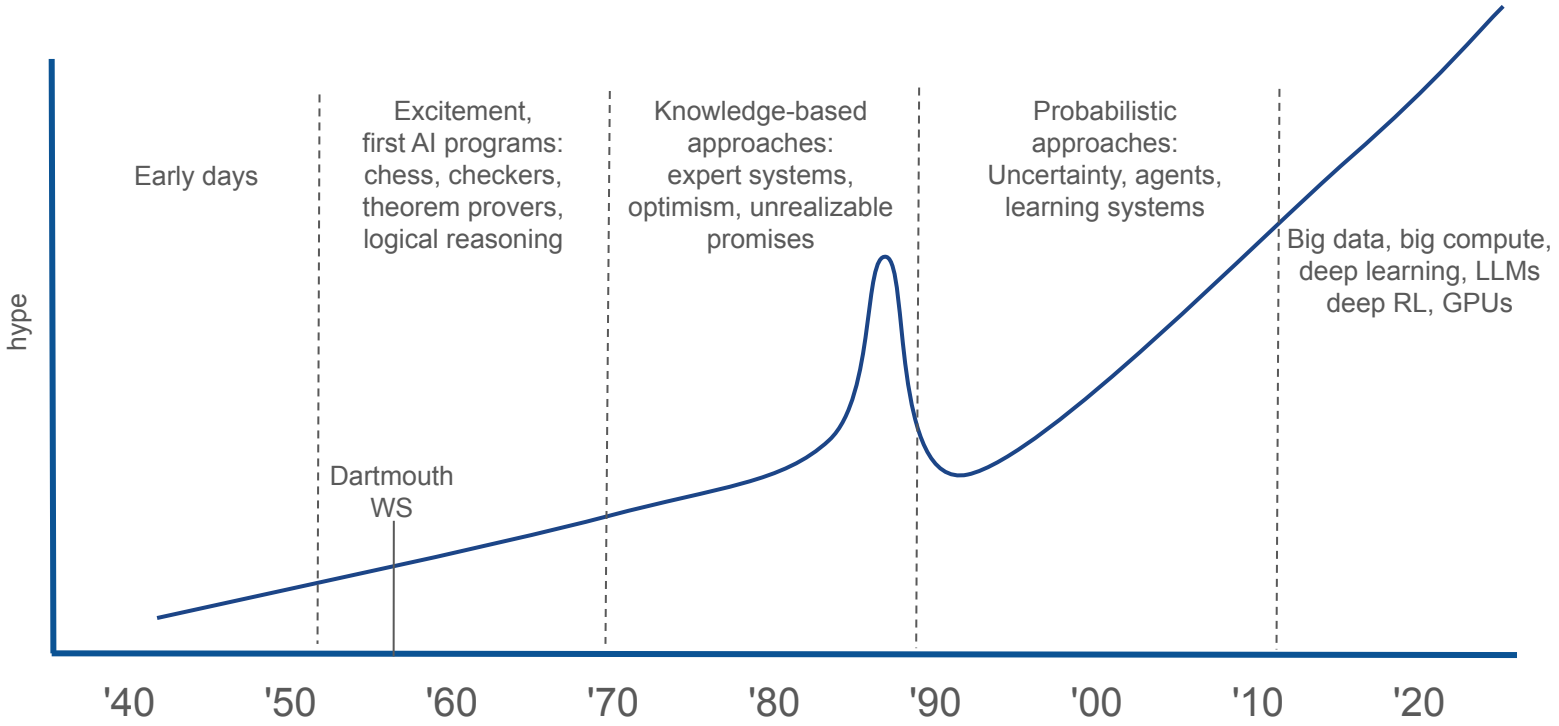
The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can ***in principle be so precisely described*** *that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a* ***significant advance can be made in one or more of these problems*** *if a carefully selected group of scientists work on it together* ***for a summer****.*

(John McCarthy and Claude Shannon, Dartmouth Workshop Proposal)

Today we see the proposal as overly optimistic (to say the least) – almost 7 decades have passed since

AI's Highs and Lows (see Ch. 1.3 for an interesting in-depth report)

Soaring expectations, significant breakthroughs, disillusionment, renewed enthusiasm



Where does AI stand?

- Autonomous Vehicles (Taxis Available in SF)
- Legged Robots (BigDog)
- Automated Translation (ChatGPT, Gemini, Translate)
- Recommender Systems (Netflix, Amazon, Investments)
- Game Playing (From DeepBlue to AlphaZero)
- Medicine (Automated Diagnosis, Image Analysis)
- Image Recognition, Tagging, etc.
- …

What can't AI do (to date)?

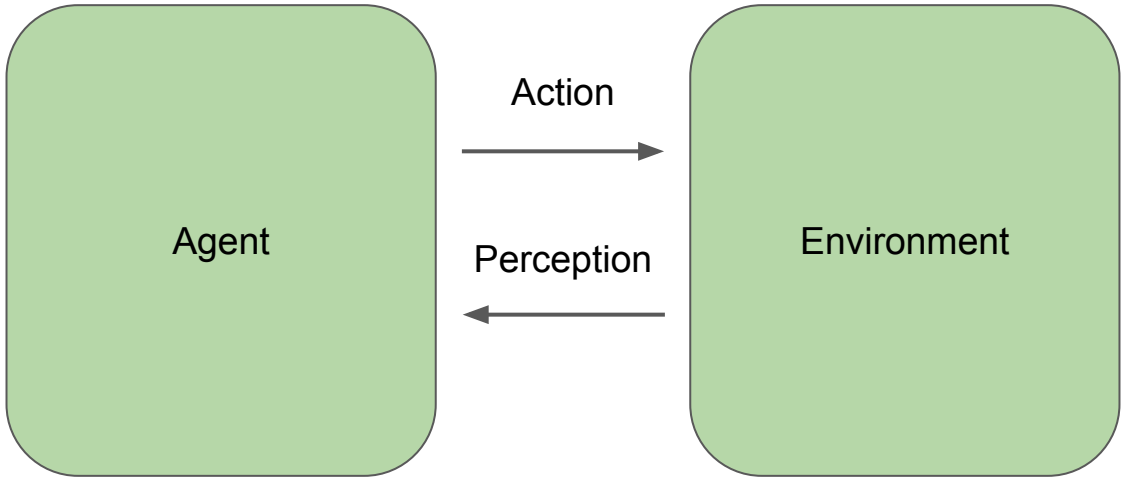
- Inductive systems can hardly explain their outputs or decisions
- Behave ethically
- Distinguishing right, wrong, good, bad
- Empathize
- Act Creatively (despite appearances)
- Context understanding (e.g., when is a sad situation funny? Sarcasm?)
- Write code (in general)
- Identify an prove interesting Math theorems
- …

Summarizing

- AI is a vast (and growing) discipline, encompassing many other
- Incredible successes achieved from inception
- Still a lot of work to be done
- We need to fully understand the basic principles

Agents

Agent: entity capable of *perceiving* and *acting* in an *environment*



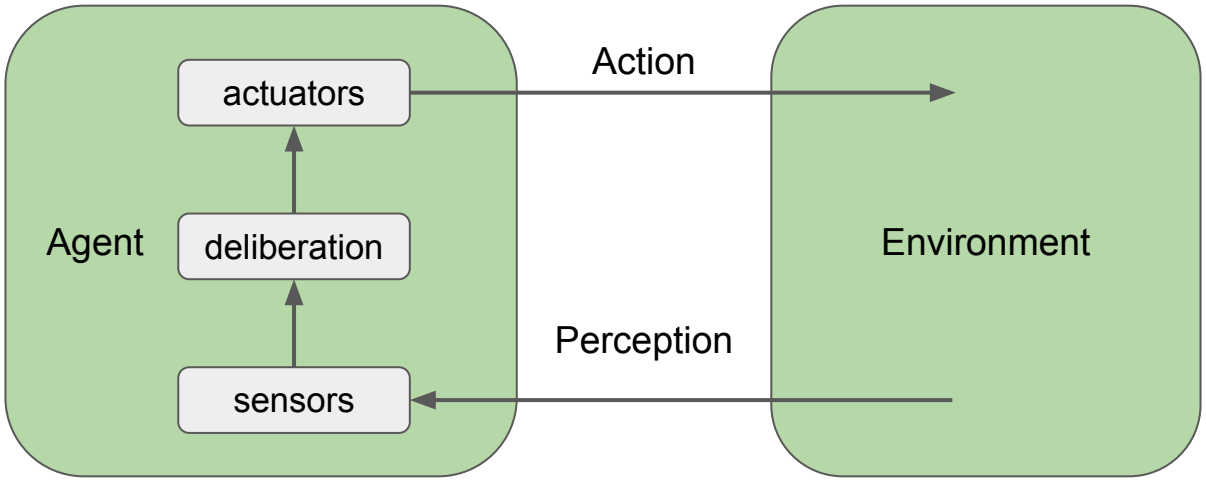
A general definition

Environment/Agent can be any

Environment	Agent
Chessboard (with Chess rules)	Software able to: - access board state (perception) - move pieces (actions)
Urban roads	Autonomous car able to: - see road/cars, check distances, access own state (perception) - accelerate, turn, stop, etc. (actions)
House	Robot able to: - recognize objects, see house/people (perception) - grasp, push, pull objects

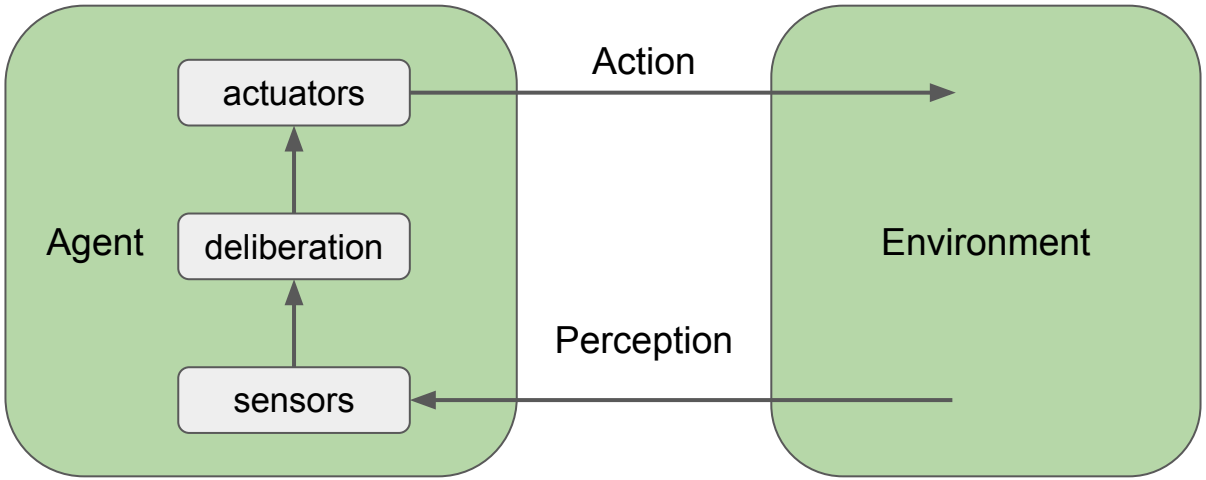
Agents

- Perceive through *sensors* (e.g., a camera)
- Act through *actuators* (a gripper)
- Deliberate through dedicated module (agent function)



Rational Agents

- *Utility* function: function returning a reward/penalty for behaving right/wrong
- Rational agents act so as to *maximize their overall (expected) utility*

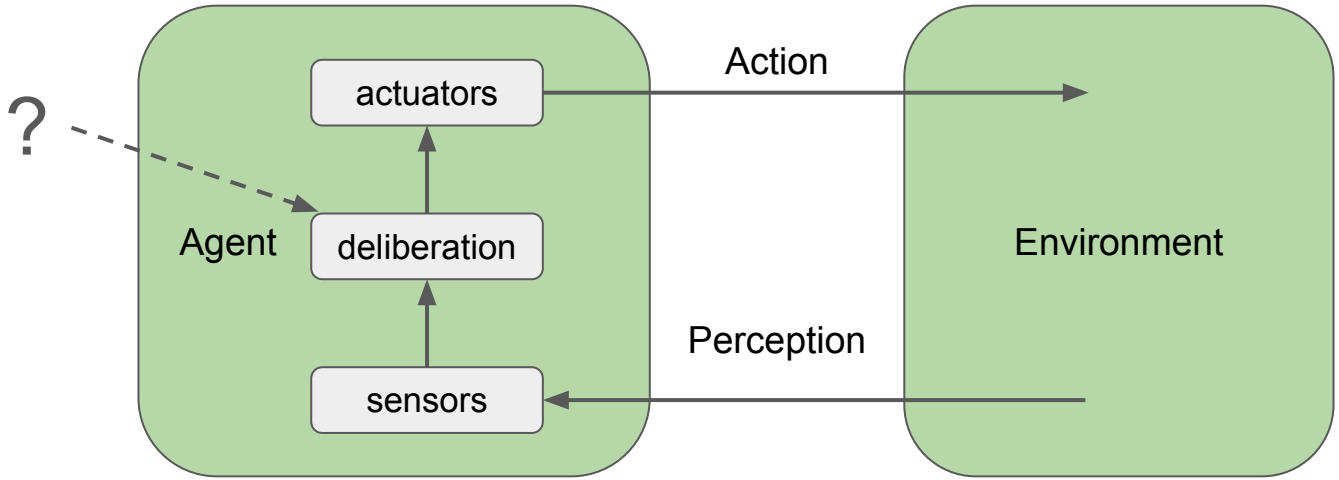


Rational Agents - Examples

- Chess:
  - Reward for capturing piece (e.g., +10, may depend on specific piece)
  - Penalty for losing a piece (e.g., -10, may depend on specific piece)
  - High reward for checkmating
  - High penalty for being checkmated
  - 0 for Tie
- Maze:
  - Penalty for every step (e.g., -1)
  - High reward for exiting
- Investing agent:
  - High reward for gaining money
  - High penalty for losing money

Rational Agents

Question: How to design (and realize) agents able to deliberate so as to maximize their utility?



Rational Agents

Question: How to design (and realize) agents able to deliberate so as to maximize their utility?

Many solution approaches, depending on nature of problem and environment

We start with *logic-based* approaches