

Introduction to Artificial Intelligence

Lecture 0: Artificial Intelligence

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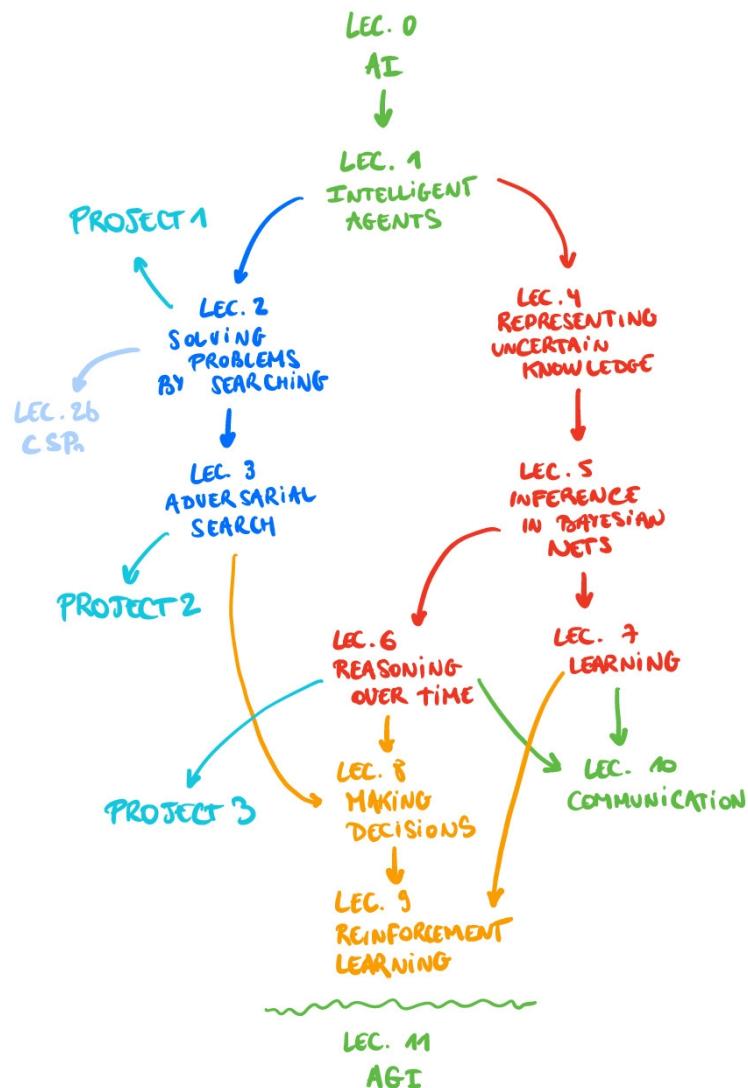


Today

- Course outline
- Introduction to Artificial Intelligence
- Intelligent agents

Outline

- Lecture 0: Artificial intelligence
- Lecture 1: Intelligent agents
- Lecture 2: Solving problems by searching
- Lecture 2b: Constraint satisfaction problems (optional)
- Lecture 3: Adversarial search
- Lecture 4: Representing uncertain knowledge
- Lecture 5: Inference in Bayesian networks
- Lecture 6: Reasoning over time
- Lecture 7: Learning
- Lecture 8: Making decisions
- Lecture 9: Reinforcement learning
- Lecture 10: Communication
- Lecture 11: Artificial General Intelligence and beyond



My mission

By the end of this course, you will have built autonomous agents that efficiently make decisions in fully informed, partially observable and adversarial settings. Your agents will draw inferences in uncertain environments and optimize actions for arbitrary reward structures.

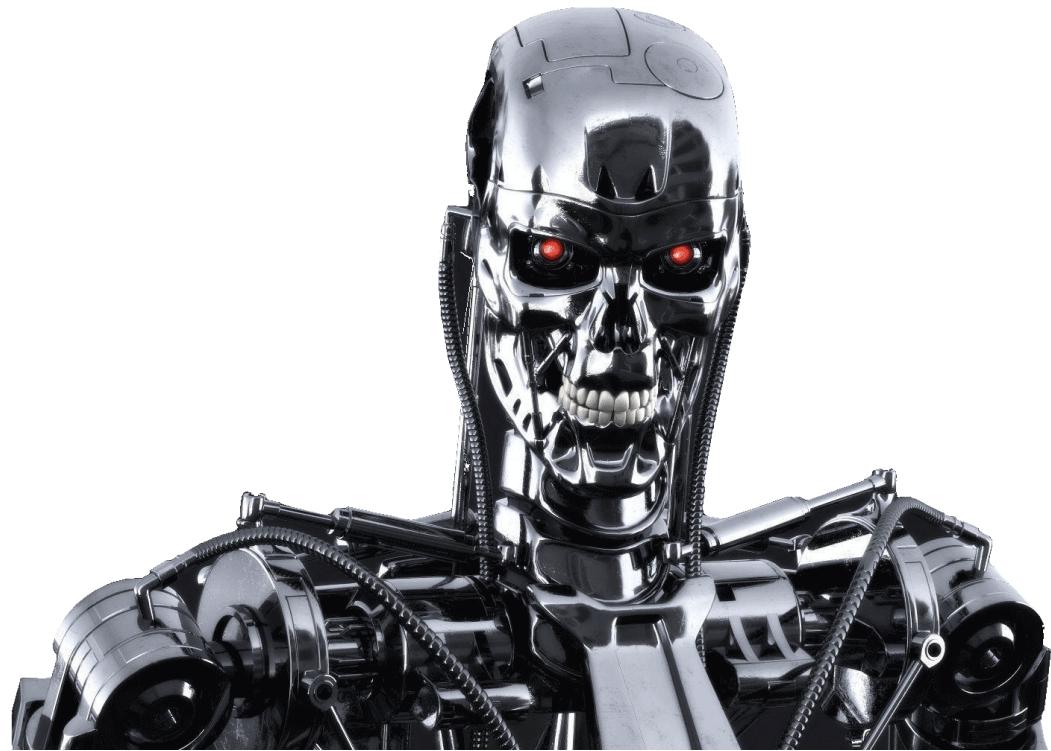
The techniques you learn in this course apply to a wide variety of artificial intelligence problems and will serve as the foundation for further study in any application area you choose to pursue.

Going further

This course is designed as an introduction to the many other courses available at ULiège and (broadly) related to AI, including:

- **INFO8006: Introduction to Artificial Intelligence** ← you are there
- ELEN0062: Introduction to Machine Learning
- INFO8004: Advanced Machine Learning
- INFO8010: Deep Learning
- INFO8003: Optimal decision making for complex problems
- INFO0948: Introduction to Intelligent Robotics
- INFO0049: Knowledge representation
- ELEN0016: Computer vision
- ELEN0060: Information and coding theory
- MATH2022: Large-sample analysis: theory and practice
- DROI8031: Introduction to the law of robots

Artificial intelligence



"With artificial intelligence we are summoning the demon" -- Elon Musk



"We're really closer to a smart washing machine than Terminator" -- Fei-Fei Li,
Director of Stanford AI Lab.



Edsger Dijkstra: *What do you work on?*

Leslie Valiant (very proudly): *Artificial Intelligence.*

Edsger Dijkstra: *Why don't you work first on the "**Intelligence**" part?*



"What is intelligence, anyway? It is only a word that people use to name those unknown processes with which our brains solve problems we call hard. But whenever you learn a skill yourself, you're less impressed or mystified when other people do the same.

*This is why **the meaning of "intelligence" seems so elusive**: it describes not some definite thing but only the momentary horizon of **our ignorance about how minds might work**. It is hard for scientists who try to understand intelligence to explain precisely what they do, since our working definitions change from year to year. But it is not at all unusual for sciences to aim at moving targets.*" -- Marvin Minsky

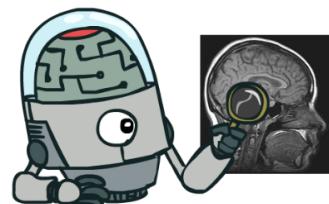
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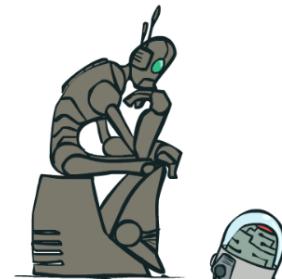
A definition?

Artificial intelligence is the science of making machines or programs that:

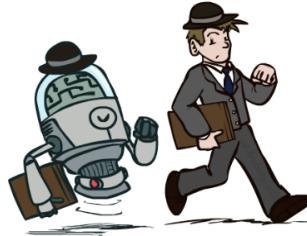
Think like people



Think rationally



Act like people



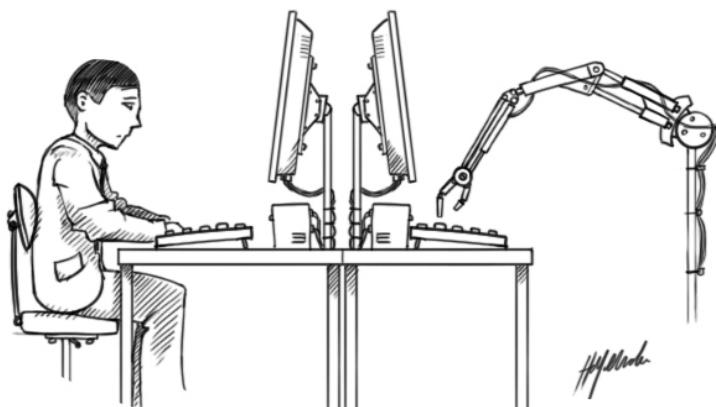
Act rationally



Acting humanly

The Turing test

A computer passes the **Turing test** (aka the Imitation Game) if a human operator, after posing some written questions, cannot tell whether the written responses come from a person or from a computer.



*Can machines think?
(Alan Turing, 1950)*

An agent would not pass the Turing test without the following **requirements**:

- natural language processing
- knowledge representation
- automated reasoning
- machine learning
- computer vision (total Turing test)
- robotics (total Turing test)

Despite being proposed almost 70 years ago, the Turing test is **still relevant** today.

The screenshot shows a web-based chat interface titled "Dash GPT-3 Chatbot Demo". At the top right are icons for "Watch later", "plost", and "Share". The main area displays a conversation between a user and the chatbot:

- User: Hey Philippe! How are you?
- Bot: I'm good. How about you?
- User: Great, thanks for asking!
- Bot: No problem. So, what have you been up to lately?
- Bot: Hm nothing much. Mostly watching Netflix, playing video games, etc. You know, all that indoor stuff lol
- User: That sounds fun. Anything in particular you've been watching or playing?
- Bot: Yeah I've been watching this show, Dark!
- User: Oh yeah? Is it anything like Stranger Things?

At the bottom, there is a text input field with placeholder text "Write to the chatbot..." and a "Submit" button.

A conversation with GPT-3 (2020)

Limitations of the Turing test

The Turing test tends to focus on **human-like errors, linguistic tricks**, etc.

However, it seems more important to study the **principles** underlying intelligence than to replicate an exemplar.



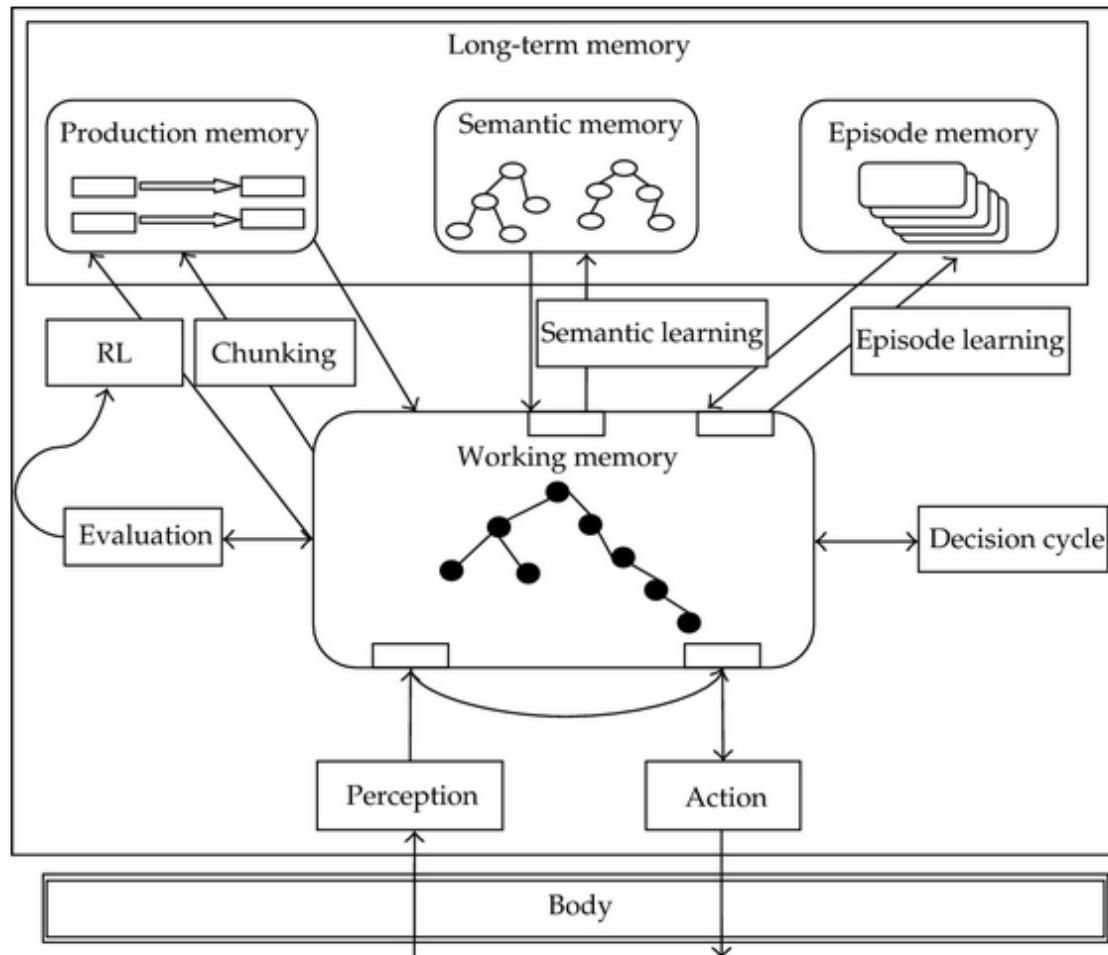
Aeronautics is not defined as the field of making machines
that fly so exactly like pigeons that they can fool even other pigeons.

Thinking humanly

Cognitive science

Study of the **human mind** and its processes.

- The goal of cognitive science is to form a theory about the structure of the mind, summarized as a comprehensive **computer model**.
- It includes language, problem-solving, decision-making and perception.
- A **cognitive architecture** usually follows human-like reasoning and can be used to produce testable predictions (time of delays during problem solving, kinds of mistakes, learning rates, etc).

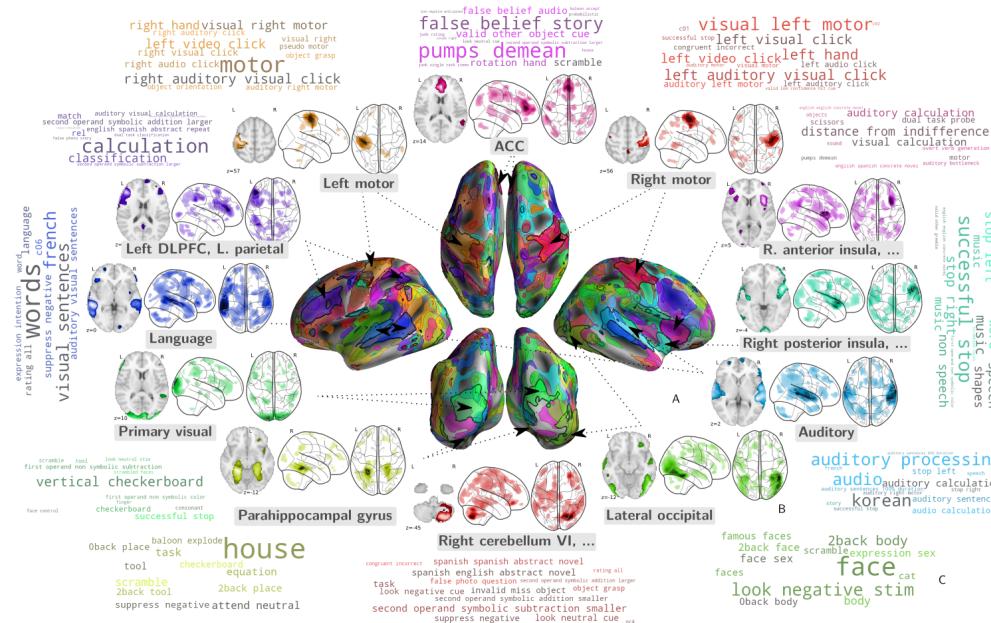


The modern SOAR cognitive architecture.

Neurobiology and neuroscience

Study of the anatomy and physiology of neural tissue.

- Neurobiology is concerned with the the **anatomy and physiology of the brain**, from major structures down to neurons and molecules.
 - Neuroscience adds to that the study of **how the brain works**, mechanistically, functionally, and systematically to produce observable behavior.



Limitations of cognition and neuroscience for AI

- In linguistics, the argument of **poverty of the stimulus** states that children do not receive sufficient input to generalize grammatical rules through linguistic input alone.
 - A baby hears too few sentences to deduce the grammar of English before he speaks correctly.
- (Controversial) Therefore, humans must be **biologically pre-wired** with **innate knowledge** for representing language.



How do we know what we know?
(Noam Chomsky, 1980)

Therefore, it may not be possible to implement a fully functioning computer model of the human mind without background knowledge of some sort.

Thinking rationally

The logical approach

- The rational thinking approach is concerned with the study of **irrefutable reasoning processes**. It ensures that all actions performed by a computer are formally **provable** from inputs and prior knowledge.
- The "laws of thought" were supposed to govern the operation of the mind. Their study initiated the field of **logic** and the **logician tradition** of AI (1960-1990).

Who owns the zebra?

- There are five houses.
- The English man lives in the red house.
- The Swede has a dog.
- The Dane drinks tea.
- The green house is immediately to the left of the white house.
- They drink coffee in the green house.
- The man who smokes Pall Mall has birds.
- In the yellow house they smoke Dunhill.
- In the middle house they drink milk.
- The Norwegian lives in the first house.
- The man who smokes Blend lives in the house next to the house with cats.
- In a house next to the house where they have a horse, they smoke Dunhill.
- The man who smokes Blue Master drinks beer.
- The German smokes Prince.
- The Norwegian lives next to the blue house.
- They drink water in a house next to the house where they smoke Blend.

```

select([A|As], S) :- select(A, S, S1), select(As, S1) .
select([], _).

next_to(A, B, C) :- left_of(A, B, C) ; left_of(B, A, C) .
left_of(A, B, C) :- append(_, [A, B|_], C) .

zebra(Owns, HS) :- % color,nation,pet,drink,smokes
    HS = [ h(_, norwegian, _, _, _), _, h(_, _, _, milk, _), _, _, _],
    select( [ h(red, englishman, _, _, _), h(_, swede, dog, _, _),
              h(_, dane, _, tea, _), h(_, german, _, _, prince) ], HS),
    select( [ h(_, _, birds, _, pallmall), h(yellow, _, _, _, dunhill),
              h(_, _, _, beer, bluemaster) ], HS),
    left_of( h(green, _, _, coffee, _), h(white, _, _, _, _), HS),
    next_to( h(_, _, _, _, dunhill), h(_, _, horse, _, _), HS),
    next_to( h(_, _, _, _, blend), h(_, _, cats, _, _), HS),
    next_to( h(_, _, _, _, blend), h(_, _, _, water, _), HS),
    next_to( h(_, norwegian, _, _, _), h(blue, _, _, _, _), HS),
    member( h(_, Owns, zebra, _, _), HS).

:- ?- time(( zebra(Who, HS), maplist(writeln, HS), nl, write(Who), nl, nl, fail
            ; write('No more solutions.'))).

```

```

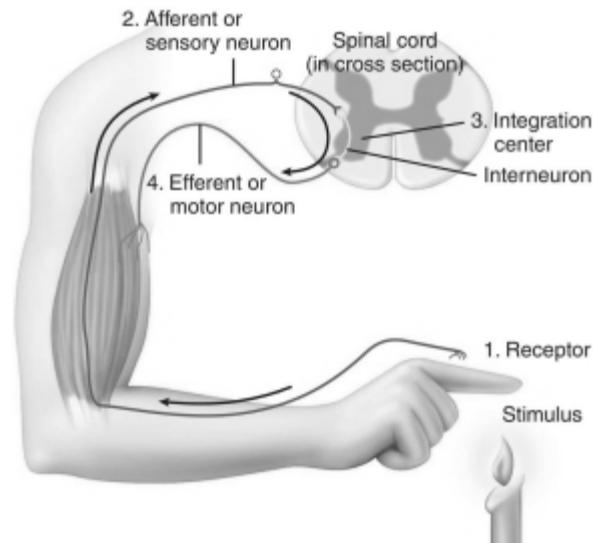
h(yellow, norwegian, cats, water, dunhill)
h(blue, dane, horse, tea, blend)
h(red, englishman, birds, milk, pallmall)
h(green, german, zebra, coffee, prince)
h(white, swede, dog, beer, bluemaster)

```

german

Limitations of logical inference

- Representation of **informal** knowledge is difficult.
- Hard to define provable **plausible** reasoning.
- Combinatorial **explosion** (in time and space).
- Logical inference is only a part of intelligence. It does not cover everything:
 - e.g., might be no provably correct thing to do, but still something must be done;
 - e.g., reflex actions can be more successful than slower carefully deliberated ones.



Pain withdrawal reflexes do not involve inference.

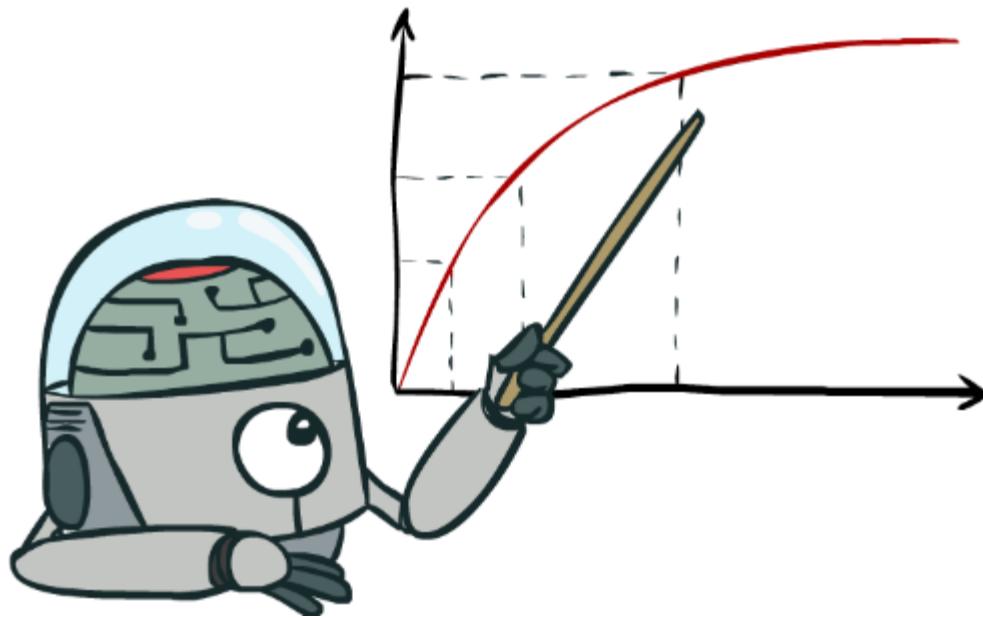
Acting rationally

A **rational agent** acts so as to achieve the **best expected** outcome.

- Correct logical inference is just one of several possible mechanisms for achieving this goal.
- Perfect rationality cannot be achieved due to computational limitations!
 - The amount of reasoning is adjusted according to available resources and importance of the result.
- The brain is good at making rational decisions but not perfect either.

Rationality only concerns **what** decisions are made (not the thought process behind them, human-like or not).

Goals are expressed in terms of the **performance** or **utility** of outcomes. Being rational means maximizing its expected performance. The standard of rationality is general and mathematically well defined.



In this course, Artificial intelligence = **Maximizing expected performance**

AI prehistory

- **Philosophy:** logic, methods of reasoning, mind as physical system, foundations of learning, language, rationality.
- **Mathematics:** formal representation and proof, algorithms, computation, (un)decidability, (in)tractability, probability.
- **Psychology:** adaptation, phenomena of perception and motor control, psychophysics.
- **Economics:** formal theory of rational decisions.
- **Linguistics:** knowledge representation, grammar.
- **Neuroscience:** plastic physical substrate for mental activity.
- **Control theory:** homeostatic systems, stability, simple optimal agent designs.

A short history of AI

1940-1950: Early days

- 1943: McCulloch and Pitts: Boolean circuit model of the brain.
- 1950: Turing's "Computing machinery and intelligence".

1950-1970: Excitement and expectations

- 1950s: Early AI programs, including Samuel's checkers program, Newell and Simon's Logic Theorist and Gelernter's Geometry Engine.
- 1956: Dartmouth meeting: "Aritificial Intelligence" adopted.
- 1958: Rosenblatt invents the perceptron.
- 1965: Robinson's complete algorithm for logical reasoning.
- 1966-1974: AI discovers computational complexity.



The Dartmouth workshop (1956)

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.



The Thinking Machine (Artificial Intelligence ...



Watch later



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1970-1990: Knowledge-based approaches

- 1969: Neural network research almost disappears after Minsky and Papert's book.
- 1969-1979: Early development of knowledge-based systems.
- 1980-1988: Expert systems industrial boom.
- 1988-1993: Expert systems industry busts (AI winter).

1990-Present: Statistical approaches

- 1985-1995: The return of neural networks.
- 1988-: Resurgence of probability, focus on uncertainty, general increase in technical depth.
- 1995-2010: New fade of neural networks.
- 1995-: Complete intelligent agents and learning systems.
- 2000-: Availability of very large datasets.
- 2010-: Availability of fast commodity hardware (GPUs).
- 2012-: Resurgence of neural networks with deep learning approaches.

What can AI do at present?

- Translate spoken Chinese to spoken English, live?
- Answer multi choice questions, as good as an 8th grader?
- Converse with a person for an hour?
- Play decently at Chess? Go? Poker? Soccer?
- Buy groceries on the web? in a supermarket?
- Prove mathematical theorems?
- Drive a car safely on a parking lot? in New York?
- Perform a surgery?
- Identify skin cancer better than a dermatologist?
- Write a funny story?
- Paint like Van Gogh? Compose music?
- Show common sense?



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So, that one change that particular breakthrough increased recognition rates by approximately thirty percent, that's a big deal.

That's the difference between going

Recognizability: 98%

Speech translation and synthesis (2012)



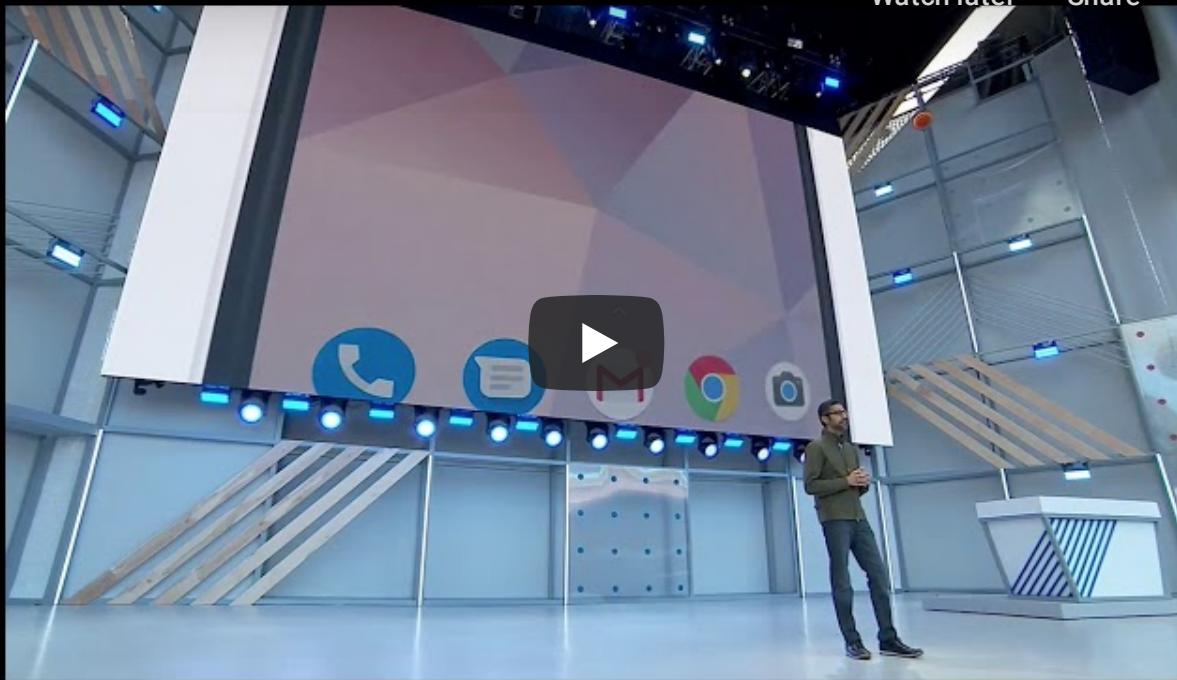
Google Assistant will soon be able to call res...



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Speech synthesis and question answering (Google, 2018)



Google DeepMind's Deep Q-learning playing ...



Watch later



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Playing Atari games



The computer that mastered Go



Watch later



Share



Beat the best human Go players (2016)



OpenAI Five



Watch later



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Beat teams of human players at real-time strategy games (Dota 2) (2018)



RoboCup 2018 Humanoid AdultSize Final: Ni...



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Playing soccer (2018)



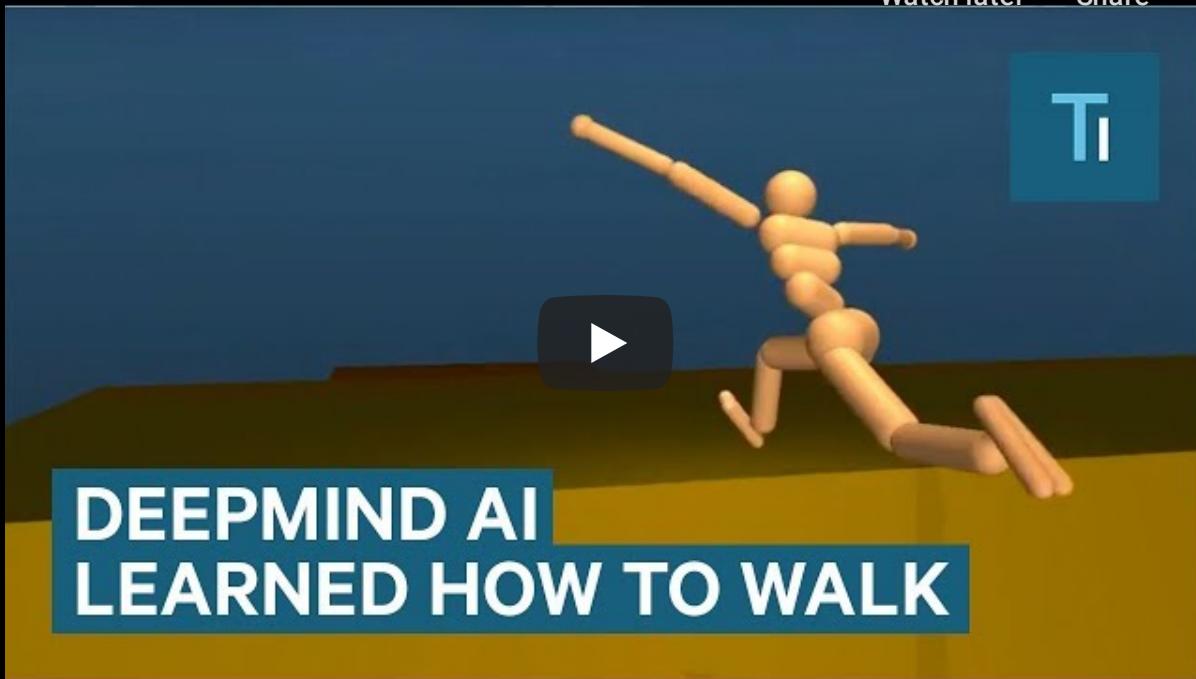
Google's DeepMind AI Just Taught Itself To ...



Watch later



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Learning to walk (2017)



NVIDIA Autonomous Car



Watch later



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Driving a car (NVIDIA, 2016)



Tesla Autopilot predicts CRASH Compilation...



Watch later



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... and preventing accidents.

FB

Detectron2: A PyTorch-based modular object detection...



Copy link



Object detection, pose estimation, segmentation (2019)



NeuralTalk and Walk, recognition, text descri...

a row of bikes parked next to each other



Watch later

Share



Generating image descriptions (2015)



Digital doctor: AI singles out skin cancer fro...



Watch later



Share



Detecting skin cancer (2017)



GTC Japan 2017 Part 9: AI Creates Original ...



Watch later



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Compose music (NVIDIA, 2017)



Learning to sort waste (before training)



Watch later



Share

Learning to sort waste, before training
(Norman Marlier, ULiège, 2018)



Learning to sort waste (after training)



Watch later



Share



Learning to sort waste, after training
(Norman Marlier, ULiège, 2018)

What is missing?

Intelligence is not just about **pattern recognition**, which is something most of these works are based on.

It is about **modeling the world**:

- explaining and understanding what we see;
- imagining things we could see but haven't yet;
- problem solving and planning actions to make these things real;
- building new models as we learn more about the world.

The end.

References

- Turing, Alan M. "Computing machinery and intelligence." *Mind* 59.236 (1950): 433-460.
- Newell, Allen, and Herbert Simon. "The logic theory machine--A complex information processing system." *IRE Transactions on information theory* 2.3 (1956): 61-79.
- Chomsky, Noam. "Rules and representations." *Behavioral and brain sciences* 3.1 (1980): 1-15.