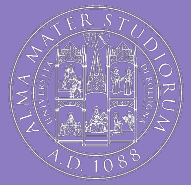

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Intelligenza Artificiale

Introduction to Artificial Intelligence

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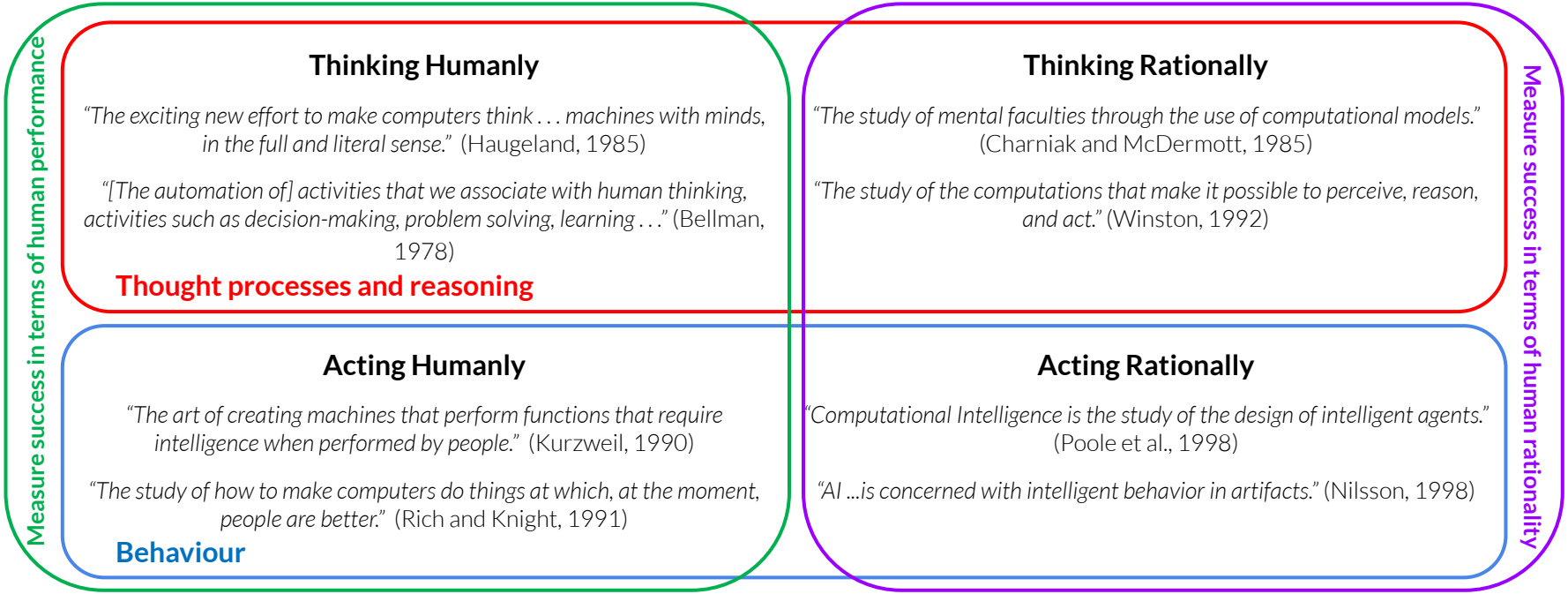
What is Artificial Intelligence?

For thousands of years we have tried to understand how we think, the field of artificial intelligence goes further since it attempts, not only to understand, but also to build intelligent entities.

Some definitions of AI:



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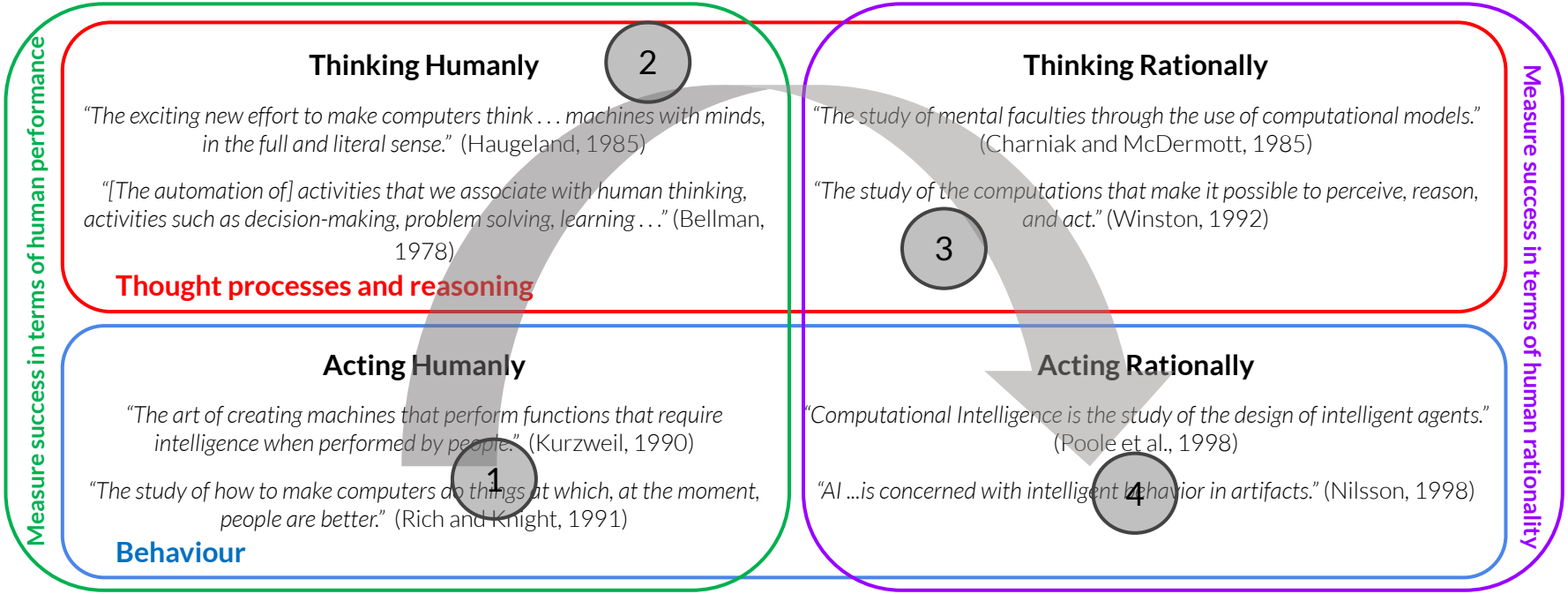


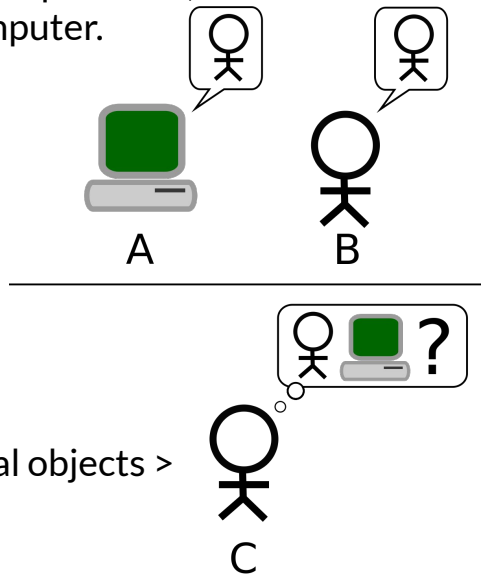
Acting Humanly: The Turing Test Approach

- The **Turing Test**, proposed by Alan Turing (1950), was designed to provide a satisfactory operational definition of intelligence.

- A computer passes the test if a human interrogator, after posing some written questions, cannot tell whether the written responses come from a person or from a computer.

- The computer would need to possess the following capabilities:
    - Natural Language Processing
    - Knowledge representation
    - Automated reasoning
    - Machine Learning

- **Total Turing Test** includes the opportunity of the interrogator to pass physical objects > other capabilities needed: Computer vision, Robotics



**GPT-4 was considered human 54% of the time, closely mimicking real human interactions.

Thinking Humanly: The Cognitive Modelling Approach

Creating program able to think requires that we have determined how humans think.

Cognitive science which brings together computer models from AI and experimental techniques from psychology to construct precise and testable theories of human mind.

(If an algorithm performs well on a task, that is therefore a good model of human performance, and vice versa)

General Problem Solver (GPS) (Newell and Simon, 1957) was designed in order to compare the trace of its reasoning steps to traces of human subjects solving the same problems

Thinking rationally: The “laws of thought” approach

The logicist tradition within artificial intelligence is focused on building on programs modelled as logical axioms about all kinds of objects in the world (or a part of it) and the relations among them

In the field of logics the laws of thought are:

- fundamental axiomatic rules upon which rational discourse itself is often considered to be based.
- supposed to govern the operation of the mind.

Aristotle was one of the first to attempt to codify “right thinking”, that is, irrefutable reasoning processes.

Syllogisms provided patterns for argument structures that always yielded correct conclusions when given correct premises

“Socrates is a man; all men are mortal; therefore, Socrates is mortal.”

Acting rationally: The rational agent approach

An **agent** is something that acts (agere)

All computer programs do something, but computer agents are expected to do more:

- Operate autonomously
- Perceive their environment
- Persist over prolonged time period
- Adapt to change
- Create and pursue goals

A **rational agent** is one that acts so as to achieve the best outcome or, when there is uncertainty, the best expected outcome.

Symbolic vs. sub symbolic approaches

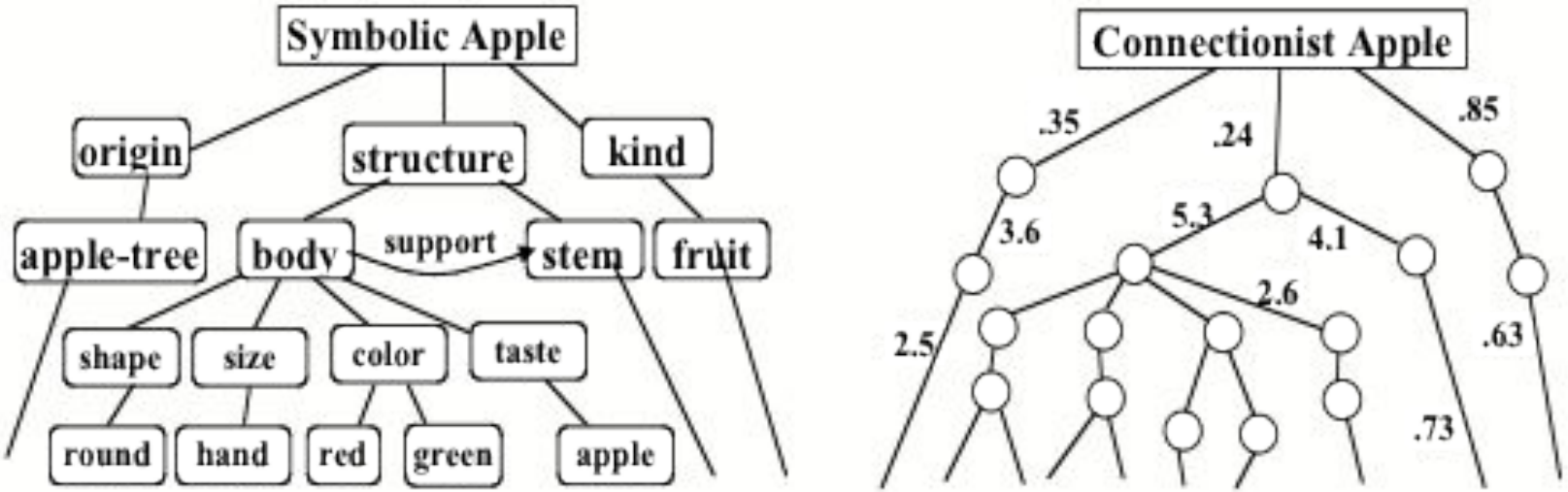


Image from (Minsky 1991). Logical Versus Analogical or Symbolic Versus Connectionist or Neat Versus Scruffy. *AI magazine*, 1991

Symbolic vs. sub symbolic approaches

SYMBOLIC	SUB-SYMBOLIC
POSITIVE (+) Easy to control (+) Easy to debug (+) Easy to explain	**POSITIVE** (+) Better performance for perceptual tasks (+) More robust against noise (+) Easier to scale up (+) Less knowledge upfront
NEGATIVE (-) Considerable effort needed to define symbols (-) Considerable effort needed to designing rules and methods to manipulate symbols to solve problems	**NEGATIVE** (-) Hard to explain (-) Need large quantity of examples to learn optimal strength

Weak/Strong AI

Weak AI, also called narrow AI, is focused on one narrow task (e.g. object detection). It aims to mimic how humans perform basic actions such as remembering, perceiving and solving simple problems.

Strong AI is an artificial intelligence artefact whose capabilities mimic the human brain. In philosophy, there is no essential difference between the piece of software, which is the AI, exactly emulating the actions of the human brain, and the actions of a human being, including its power of understanding and even its consciousness. **Artificial General Intelligence (AGI)** is the ability to apply intelligence to any problem, rather than just one specific problem.

Foundations of Artificial Intelligence

- Philosophy
- Mathematics
- Economics
- Neuroscience
- Psychology
- Computer engineering

Foundations of Artificial Intelligence: Philosophy (1)

- *Can formal rules be used to draw valid conclusions?*
- *How does the mind arise from the physical brain?*
- *Where does knowledge come from?*
- *How does knowledge lead to action?*

Aristotele (384-322 BC) was the first to formulate a precise set of laws governing the rational part of the mind. He developed an informal system of syllogism for proper reasoning, which in principle allowed one to generate conclusions mechanically, given initial premises.

Ramon Llull (d. 1315): reasoning could be carried out by mechanical artefacts.

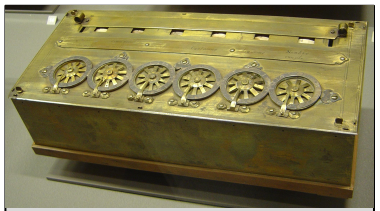
Leonardo Da Vinci (1452-1519) designed a mechanical calculator

Hobes (1588-1679): reasoning as numerical computation.

Willhelm Schickard (1592-1635) built a calculating machine

Blaise Pascal (1623-1662) built a more famous calculating machine

Leibniz (1646-1717) built a machine to carry out operation on concepts rather than numbers



Un esemplare di pascalina

Foundations of Artificial Intelligence: Philosophy (2)

Doctrines:

- **Rationalism** (knowledge is acquired by reason without resorting to experience)
- **Empiricism** (the general rules are acquired by exposure to repeated associations between their elements)
- **Dualism** (there is a part of human mind which is outside of nature)
- **Materialism** (the brain's operations according to the laws of physics constitute the human mind)
- **Logical positivism** (knowledge can be characterized logical theories connected that correspond to sensory inputs)

Foundations of Artificial Intelligence: Mathematics

- *What are the formal rules to draw valid conclusions?*
- *What can be computed?*
- *How do we reason with uncertain information?*

Mathematical formalization made AI a formal science.

Fundamental areas:

- Logic (how to describe things by using formulas)
- Computation (how to compute things by using algorithms)
- Probability (how to reason in case of uncertainty)

Foundations of Artificial Intelligence: Mathematics: Logic

The idea of formal logic can be traced back to philosophers of ancient Greece

George Boole (1815-1864) worked out the details of propositional logic, or Boolean logic.

Gottlob Frege (1848-1925) extended Boole's logic to include objects and relations => First Order Logic (FOL)

Alfred Tarski (1902-1983) introduced a theory of reference that shows how to relate the objects in a logic to objects in the real world.

Foundations of Artificial Intelligence: Mathematics: Algorithms

An algorithm is a finite sequence of well-defined, computer-implementable instructions, typically to solve a class of problems or to perform a computation.

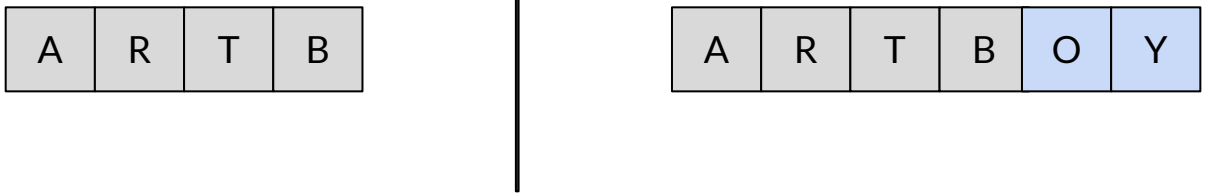
Kurt Gödel (1906-1978) showed that there exists an effective procedure to prove any true statement in first order logic (FOL). Gödel also proved that there are statements that are undecidable (i.e. for some formula is impossible to prove that the formula is true or false).

Alan Turing (1912-1954) characterized which functions are computable (i.e. capable of being computed by an algorithm). In general, no machine can tell whether a given program will return an answer on a given input or run forever.

Tractability: a problem is called intractable if the time required to solve instances of the problem grows exponentially with the size of the instances. E.G. the salesman problem is intractable.

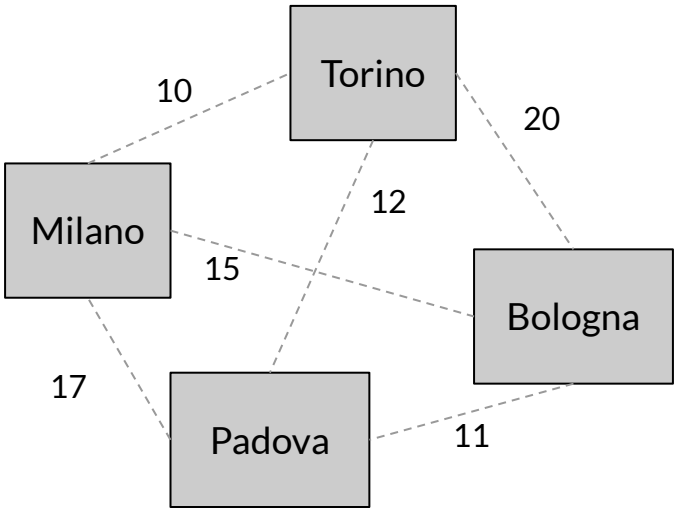
Tractability: tractable problem

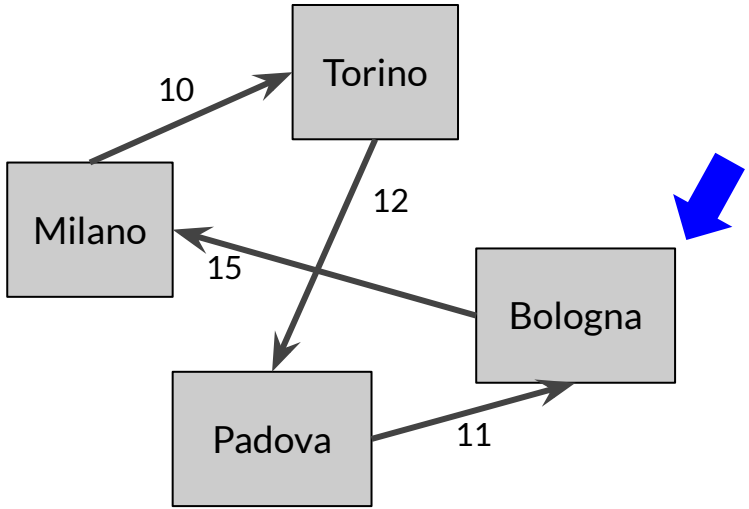
Tractable: Search for R in a **list**



Tractability: intractable problem

Intractable: the Traveling Salesman Problem (TSP): *given a set of cities and the distances between each pair of cities, the Traveling Salesman Problem seeks to find the shortest possible route that visits each city exactly once and returns to the origin city.*





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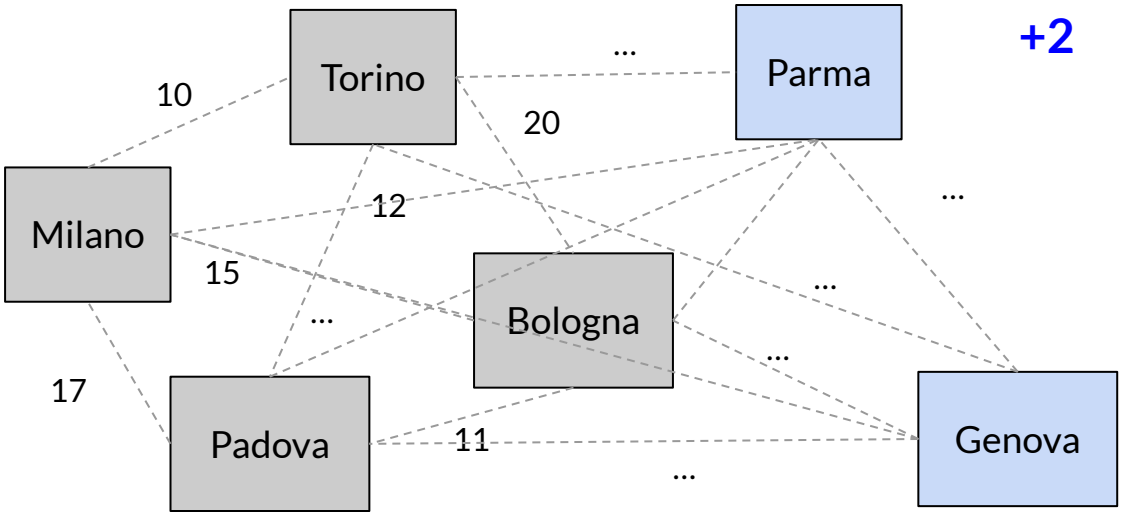


Foundations of Artificial Intelligence: Economics

- How should we make decisions so as to maximize payoff?
- How should we do this when others may not go along?
- How should we do this when the payoff may be far in the future?

Adam Smith (1723-1790) was the first to treat economics thought as a science, using the idea that economies can be thought as consisting of individual agents maximising their own well-being.

- Utility theory
- Decision theory
- Game theory

Game theory – the prisoner's dilemma example

Two suspects (A and B) in a crime are arrested; but the police do not have enough evidence to convict them. They are interrogated separately and offered two deals:

(years in prison for A, years in prison for B)

	B - collaborate	**B - don't collaborate**
A – collaborate	(6,6)	(0,7)
A - don't collaborate	(7,0)	(1,1)

Foundations of Artificial Intelligence: Neuroscience

- How do brains process information?

Neuroscience is the study of the nervous system, particularly the brain.

"At some point in the future, cognitive neuroscience will be able to describe the algorithms that drive structural neural elements into the physiological activity that results in perception, cognition, and perhaps even consciousness. To reach this goal, the field has departed from the more limited aims of neuropsychology and basic neuroscience. Simple descriptions of clinical disorders are a beginning, as is understanding basic mechanisms of neural action. The future of the field, however, is in working toward a science that truly relates brain and cognition in a mechanistic way." (M. S. Gazzaniga, "Preface", in The Cognitive Neurosciences, M. S. Gazzaniga, Ed., MIT Press, Cambridge, Mass, USA, 1995.)

Foundations of Artificial Intelligence: Psychology

- How do humans think and act?

Both **psychology** and **AI** try to understand processes that give rise to intelligent behaviour.

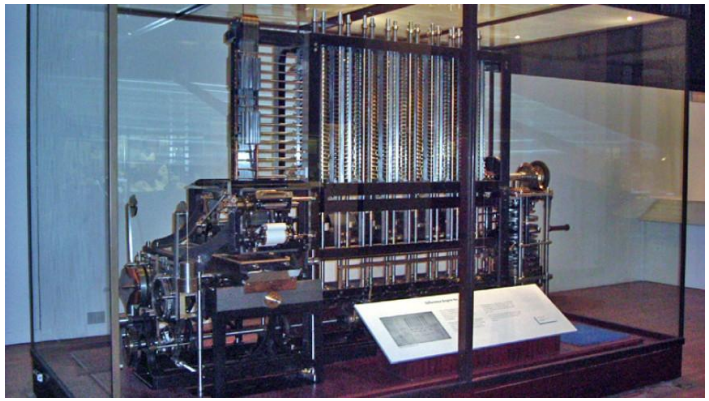
In the case of psychology, the study focuses on human beings and we talk about mental processes.

In the case of AI, the study focuses on machines and we talk about information processes.

Foundations of Artificial Intelligence: Computer Engineering

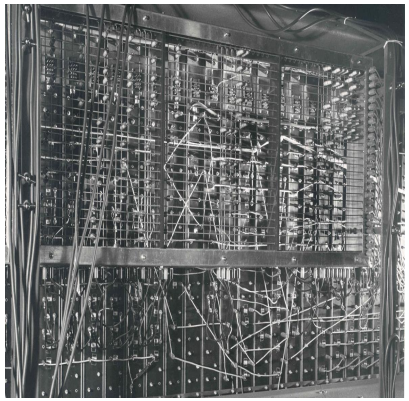
- How do we build an efficient computer?

For artificial intelligence to succeed, we need: intelligence and artifact.



Charles Babbage (1833)

Enigma



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