Artificial Intelligence

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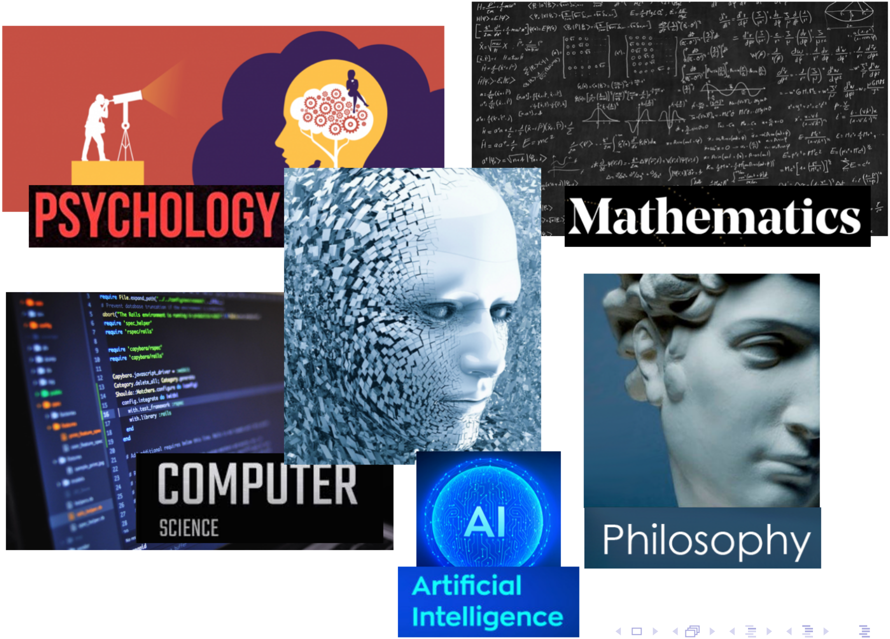
Artificial Intelligence as an interdisciplinary field



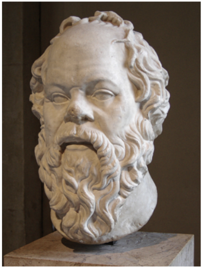
Historical perspective. Philosophy (428 B.C - Present)

- Socrates, Plato and Aristotle (Notion of piety + Syllogisms). First attempt at describing the laws governing the rational part of the mind

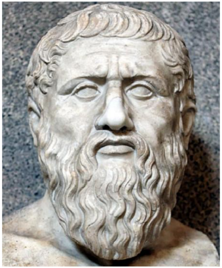
All men are mortal.
Socrates is a man.
Therefore, Socrates is mortal.

Historical perspective. Philosophy (428 B.C - Present)

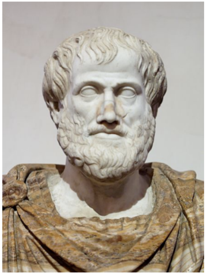
- From a set of rules, we can try to understand the mind as a physical system: Descartes (1596 - 1650). First clear distinction between Mind and Matter
  - One problem with a purely physical conception of the mind is that it leaves no space for free will
  - Despite being an advocate of reasoning, Descartes was also a proponent of Dualism (Mind and Body are distinct and separable)
- An alternative to dualism is Materialism, a view whose first advocate was probably Wilhelm Leibnitz (1646-1716). Leibnitz actually tried to build a mechanical device to demonstrate his view. Unfortunately, his formulation of logic was too weak for the device to produce interesting results.



Socrates



Plato

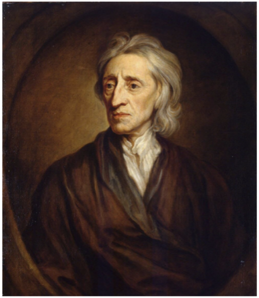


Aristotle

Descartes

Leibniz

Bacon



Locke

Historical perspective. Philosophy (428 B.C - Present)

- Following from this line of work, one of of the views in AI thus considers the mind as a physical device operating on the knowledge that it contains. If we follow that line (which is still only one possible choice), the next question becomes : where does the knowledge come from?

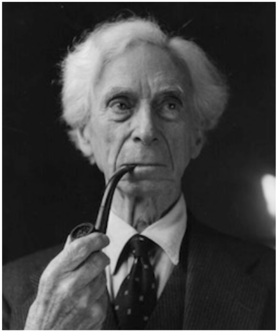
- The empiricist movement which starts with the work of Francis Bacon (1632 - 1704) relies on a dictum of John Locke (1632 - 1704): "Nothing is in the understanding which was not first in the sense".

- In *A Treatise of Human Nature* (1739-1740), David Hume (1711 - 1776) propose a first connection between understanding and the senses through what is now known as the principle of induction: Rules are acquired by exposure to repeated associations between their elements.

Historical perspective. Philosophy (428 B.C - Present)

- The Theory of Hume was later refined by Bertrand Russell (1872 - 1970) who introduced logical positivism: All knowledge can be charaterized by logical theories connected, ultimately to Observation sentences corresponding to sensory inputs.
- The Confirmation Theory of Rudolf Carnap and Carl Hempel attempts to establish the nature of the observations and the more general theories. I.e understand how knowledge can be acquired from experience.

Hume



Russell

Carnap

Hempel

Historical perspective. Philosophy (428 B.C - Present)

- Now that sensory inputs are connected to reasoning, a final ingredient is the connection between reasoning and action. Aristotle already provided some sort of answer to this question in his Nichomachean Ethics

  For a doctor does not deliberate whether he shall heal, nor an orator whether he shall persuade, nor a statesman whether he shall produce law and order, nor does any one else deliberate about his end. They assume the end and consider how and by what means it is attained, and if it seems easily and best produced thereby; while if it is achieved by one means only they consider how it will be achieved by this and by what means this will be achieved, till they come to the first cause

Historical perspective. Philosophy (428 B.C - Present)

- This idea of Aristotle was implemented by Newell and Simon, 1972 in their General Problem Solver Program (GPS). GPS was the first computer program which separated its knowledge of problems (rules represented as input data) from its strategy of how to solve problems (a generic solver engine)

- The main methods of the GPS program jointly embody the heuristic of means-ends analysis:

  I want to take my son to nursery school. What's the difference between what I have and what I want? One of distance. What changes distance? My automobile. My automobile won't work. What is needed to make it work?

Mill

Newell and Simon

Historical perspective. Philosophy (428 B.C - Present)

- Means-ends analysis is an interesting first approach but it does not say what to do when several actions will achieve the goal

- John Stuart Mill's (1806-1873) book Utilitarianism (Mill, 1863) amplifies on an original idea of Arnauld, a follower of Descartes, which studies quantitative formulas for deciding which action to take in such case.

  Actions are right in the proportion as they tend to promote happiness, wrong as they tend to produce the reverse of happiness". By happiness Mill means, *intended pleasure, and the absence of pain; by unhappiness, pain, and the privation of pleasure*

- In the framework of AI, an agent should select the action which maximizes a well defined utility measure.

Historical perspective. Mathematics (c. 800 - Present)

- Philosophers underlined the most important ideas in AI, yet the leap to a formal science required a level of mathematical formalization in three main areas: computation, logic, and probability

- The notion of expressing a computation as a formal algorithm goes back to al-Khowarazmi an Arab mathematician of the nineth century

- Logic goes back at least to Aristotle, but it was a philosophical rather than mathematical subject until George Boole (1815-1864) introduced his formal language for making logical inference in 1847

- 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.

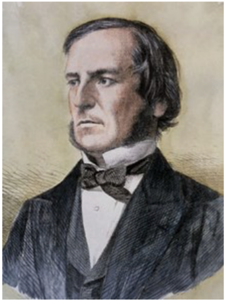
Historical perspective. Mathematics (c. 800 - Present)

- The next step was to determine the limits of what could be done with logic and computation. In 1900, David Hilbert presented a list of 23 problems that he correctly predicted would occupy mathematicians for the bulk of the century. The final problem asks if there is an algorithm for deciding the truth of any logical proposition involving the natural numbers

- Hilbert was asking if there were fundamental limits to the power of effective proof procedures. In 1930, Kurt Godel (1906-1978) showed that there exists an effective procedure to prove any true statement in the first-order logic of Frege and Russell

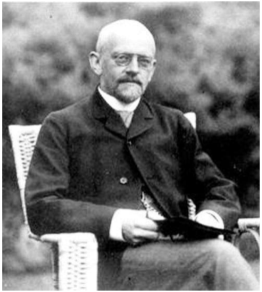
- In 1931, he showed that real limits do exist. His incompleteness theorem showed that in any language expressive enough to describe the properties of the natural numbers, there are true statements that are undecidable: their truth cannot be established by any algorithm.

al-Khowarazmi

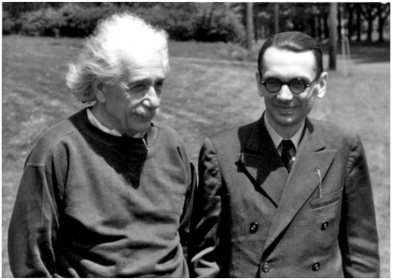


Boole

Tarski



Hilbert



Godel

Historical perspective. Mathematics (c. 800 - Present)

- This fundamental result can also be interpreted as showing that there are some functions on the integers that cannot be represented by an algorithm—that is, they cannot be computed. This motivated Alan Turing (1912-1954) to try to characterize exactly which functions are capable of being computed

- This notion is actually slightly problematic, because the notion of a computation or effective procedure really cannot be given a formal definition. Nonetheless, the Church-Turing thesis states that *A function on the natural numbers is computable (i.e. can be calculated by an effective method) if and only if it is computable by a Turing machine*

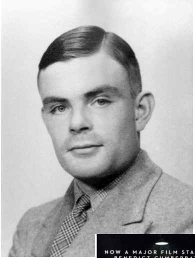
- There has never been a proof, but the evidence for its validity comes from the fact that every realistic model of computation, yet discovered, has been shown to be equivalent

Historical perspective. Mathematics (c. 800 - Present)

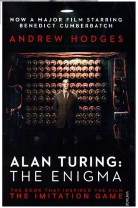
- Turing also showed that there were some functions that no Turing machine can compute. I.e no machine can tell in general (On the class of every existing problems) whether a given program will return an answer on a given input, or run forever.

- Although undecidability and noncomputability are important to an understanding of computation, the notion of intractability has had a much greater impact.

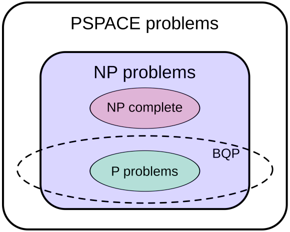
- Roughly speaking, a class of problems is called intractable if the time required to solve instances of the class grows at least exponentially with the size of the instances. The distinction between polynomial and exponential growth in complexity was first emphasized in the mid-1960s (Cobham, 1964; Edmonds, 1965)



Turing



Cobham



Edmonds

Historical perspective. Mathematics (c. 800 - Present)

- It is important because exponential growth means that even moderate-sized instances cannot be solved in any reasonable time

- Therefore, a good approach could be to divide the overall problem of generating intelligent behavior into tractable subproblems rather than intractable ones.

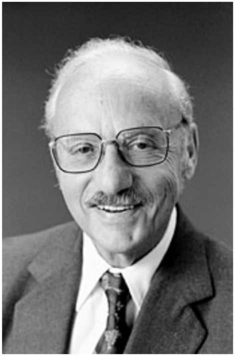
- A important concept in the theory of complexity is the notion of reduction, which also emerged in the 1960s (Dantzig, 1960; Edmonds, 1962). A reduction is a general transformation from one class of problems to another, such that solutions to the first class can be found by reducing them to problems of the second class and solving the latter problems.

Historical perspective. Mathematics (c. 800 - Present)

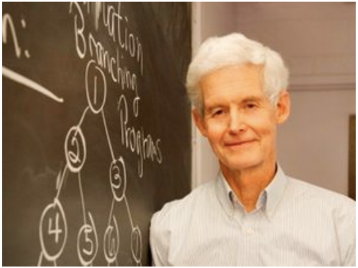
- How can one recognize an intractable problem? The theory of NP-completeness, pioneered by Steven Cook (1971) and Richard Karp (1972), provides a method. Cook and Karp showed the existence of large classes of canonical combinatorial search and reasoning problems called NP-complete.

- A decision problem C is NP-complete if:
  - C is in NP (each input to the problem should be associated with a set of solutions of polynomial length, whose validity can be tested quickly (in polynomial time).
  - Every problem in NP is reducible to C in polynomial time.[2]

- Moreover, any problem class to which an NP-complete problem class can be reduced is likely to be intractable. (Although it has not yet been proved that NP-complete problems are necessarily intractable, few theoreticians believe otherwise.)

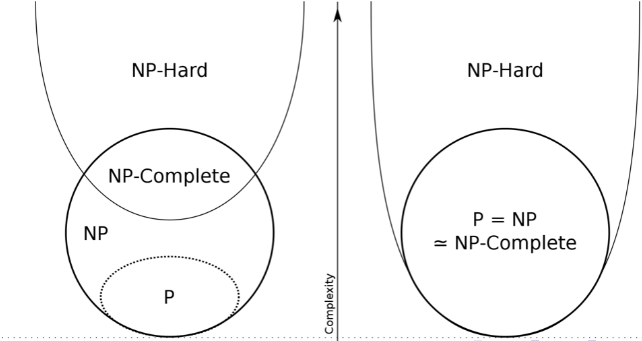


Dantzig



Cook

Karp



Historical perspective. Mathematics (c. 800 - Present)

- Besides logic and computation, the third great contribution of mathematics to AI is the theory of probability.
- The Italian Gerolamo Cardano (1501-1576) first framed the idea of probability, describing it in terms of the possible outcomes of gambling events.
- Pierre Fermat (1601-1665), Blaise Pascal (1623-1662), jacob Bernoulli (1654-1705), Pierre Laplace (1749-1827), and others advanced the theory and introduced new statistical methods.

Cardan

Bernoulli

Pascal

Fermat

Laplace

Historical perspective. Mathematics (c. 800 - Present)

- Bernoulli also framed an alternative view of probability, as a subjective "degree of belief" rather than an objective ratio of outcomes. Subjective probabilities therefore can be updated as new evidence is obtained.

- Thomas Bayes (1702-1761) proposed a rule for updating subjective probabilities in the light of new evidence (published posthumously in 1763). Bayes' rule, and the subsequent field of Bayesian analysis form the basis of the modern approach to uncertain reasoning in AI systems. Debate still rages between supporters of the objective and subjective views of probability

- As with logic, a connection must be made between probabilistic reasoning and action. Decision theory, pioneered by John Von Neumann and Oskar Morgenstern (1944), combines probability theory with utility theory

Bayes

Von Neumann

Morgenstern

Historical perspective. Psychology (c. 1879 - Present)

- Scientific psychology can be said to have begun with the work of the German physicist Hermann von Helmholtz (1821-1894) and his student Wilhelm Wundt (1832-1920). Helmholtz applied the scientific method to the study of human vision, and his Handbook of Physiological Optics

- In 1879, the same year that Frege launched first-order logic, Wundt opened the first laboratory of experimental psychology at the University of Leipzig

- Wundt insisted on carefully controlled experiments in which his workers would perform a perceptual or associative task while introspecting on their thought processes

- The consequence of introspection was that each laboratory started reporting introspective data that just happened to match the theories that were popular in this laboratory

von Helmholtz

Wundt

Historical perspective. Psychology (c. 1879 - Present)

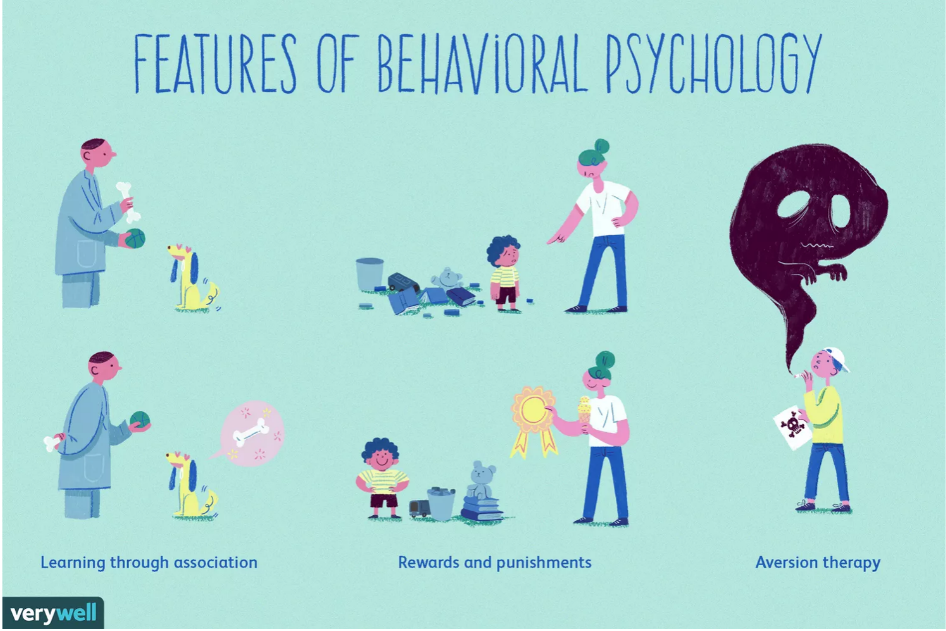
- The behaviorism movement of John Watson (1878-1958) and Edward Lee Thorndike (1874-1949) rebelled against this subjectivism, rejecting any theory involving mental processes on the grounds that introspection could not provide reliable evidence. Behaviorists insisted on studying only objective measures of the percepts (or stimulus) given to an animal and its resulting actions
- Behaviorism discovered a lot about rats and pigeons, but had less success understanding humans. Nevertheless, it had a stronghold on psychology (especially in the United States) from about 1920 to 1960

Watson

Thorndike

Historical perspective. Psychology (c. 1879 - Present)

- Key ideas of behaviorism: Behavior can be described and explained without making ultimate reference to mental events or to internal psychological processes. The sources of behavior are external (in the environment), not internal (in the mind, in the head).
- Observable behavior is essentially conditionned either by
  - The reflex response mechanisms following a particular stimulus
  - The history of interactions of an individual with its environment, namely through past punishments and rewards/reinforcements.
  - Associations

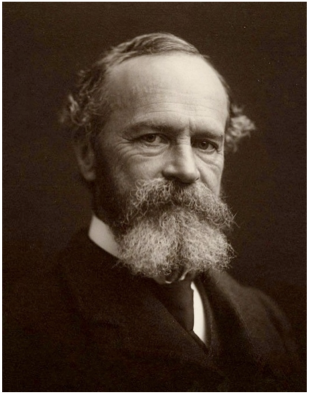


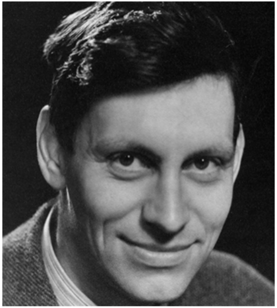
Verywell / Jiaqi Zhou

Historical perspective. Psychology (c. 1879 - Present)

- The view that the brain possesses and processes information, which is the principal characteristic of cognitive psychology, can be traced back at least to the works of William James (1842-1910). Helmholtz also insisted that perception involved a form of unconscious logical inference.
- The cognitive viewpoint was largely eclipsed by behaviorism until 1943, when Kenneth Craik published The Nature of Explanation

William James





Craik

Historical perspective. Psychology (c. 1879 - Present)

- Craik put back the missing mental step between stimulus and response. He claimed that beliefs, goals, and reasoning steps could be useful valid components of a theory of human behavior, and are just as scientific as, say, using pressure and temperature to talk about gases.
- Craik specified the three key steps of a knowledge-based agent:

  1. The stimulus must be translated into an internal representation,
  2. The representation is manipulated by cognitive processes to derive new internal representations,
  3. These are in turn retranslated back into action

Historical perspective. Psychology (c. 1879 - Present)

If the organism carries a "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and future, and in every way to react in a much fuller, safer, and more competent manner to the emergencies which face it. (Craik, 1943)

Historical perspective. Computer Science (c. 1940 - Present)

- For artificial intelligence to succeed, we need two things: intelligence and an artifact. The computer has been unanimously acclaimed as the artifact with the best chance of demonstrating intelligence.

Historical perspective. Computer Science (c. 1940 - Present)

- The modern digital electronic computer was invented independently and almost simultaneously by scientists in three countries embattled in World War II.

  1. The first operational modern computer was the Heath Robinson built in 1940 by Alan Turing's team for deciphering German messages
  2. The first operational programmable computer was the Z-3, the invention of Konrad Zuse in Germany in 1941.
  3. In the US, the first electronic computer, the ABC, was assembled by John Atanasoff and his graduate student Clifford Berry between 1940 and 1942 at Iowa State University. Two other computer projects were started as secret military research: The Mark and ENIAC.