History of AI

Foundations from related fields

Philosophy (400 B.C-)

- Socrates->Plato->Aristotle
  - Socrates: "I want to know what is characteristic of piety which makes all actions pious...that I may have it to turn to, and to use as a standard whereby to judge your actions and those of other men" (algorithm)
  - Aristotle: Try to formulate laws of rational part of the mind. Believed in another part, intuitive reason

Philosophy: Dualism vs. materialism

- Rene Descartes (1596-1650): *dualism* (part of mind that is outside of nature)
- *Materialism*. Wilhelm Leibniz (1646-1716) built a mechanical device to carry out mental operations; could not produce interesting results

Philosophy: Source of knowledge

- *Empiricism* (Francis Bacon 1561-1626)
  - John Locke (1632-1704): "Nothing is in the understanding which was not in the senses"
  - David Hume (1711-1776): Principle of induction: General rules from repeated associations between their elements
    - Bertrand Russell (1872-1970): *Logical positivism*: All knowledge can be characterized by logical theories connected, ultimately, to observed sentences that correspond to sensory inputs

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Mathematics

- Logic
  - George Boole (1815-1864): formal language for making logical inference
  - Gottlob Frege (1848-1925): First-order logic (FOL)
  - Computability
    - David Hilbert (1862-1943): Problem #23: is there an algorithm for deciding the truth of any logical proposition involving the natural numbers?
    - Kurt Godel (1906-1978): No: undecidability (yes for FOL)
    - Alan Turing (1912-1954): which functions are computable?
      - Church-Turing thesis: any computable function is computable via a Turing machine
      - No machine can tell in general whether a given program will return an answer on a given input, or run forever

Mathematics…

- Intractability
  - Polynomial vs. exponential (Cobham 1964; Edmonds 1965)
  - Reduction (Dantzig 1960, Edmonds 1962)
  - NP-completeness (Steven Cook 1971, Richard Karp 1972)
  - Contrasts "Electronic Super-Brain"

Mathematics…

- Probability
  - Gerolamo Cardano (1501-1576): probability in gambling
  - Pierre Fermat (1601-1665), Blaise Pascal (1623-1662), James Bernoulli (1654-1705), Pierre Laplace (1749-1827): new methods
  - Bernoulli: subjective beliefs->updating
  - Thomas Bayes (1702-1761): updating rule
- Decision theory = probability theory + utility theory
  - John Von Neumann & Oskar Morgenstern 1944
- Game theory

Psychology (1879-)

- Scientific methods for studying human vision
  - Hermann von Helmholtz (1821-1894), Wilhelm Wundt (1832-1920)
- Introspective experimental psychology
  - Wundt
  - Results were biased to follow hypotheses
- Behaviorism (prevailed 1920-1960)
  - John Watson (1878-1958), Edward Lee Thorndyke (1874-1949)
  - Against introspection
  - Stimulus-response studies
  - Rejected knowledge, beliefs, goals, reasoning steps

Psychology

- Cognitive psychology
  - Brain posesses and processes information
  - Kenneth Craik 1943: knowledge-based agent:
    - Stimulus -> representation
    - Representation is manipulated to derive new representations
    - These are translated back into actions
  - Widely accepted now
  - Anderson 1980: "A cognitive theory should be like a computer program"

Computer engineering

- *Abacus* (7000 years old)
- *Pascaline*: mechanical adder & substractor (Pascal; mid 1600's)
  - Leibniz added multiplication, 1694
- *Analytic Engine*: universal computation; never completed (ideas: addressable memory, stored programs, conditional jumps)
  - Charles Babbage (1792-1871), Ada Lovelace

Computer engineering…
[See Wired magazine late Fall 1999]

- *Heath Robinson*: digital electronic computer for cracking codes
  - Alan Turing 1940, England
- *Z-3*: first programmable computer
  - Konrad Zuse 1941, Germany
- *ABC*: first electronic computer
  - John Atanasoff 1940-42, US
- *ENIAC*: first general-purpose, electronic, digital computer
  - John Mauchy & John Eckert

History of AI

AI proper

Birth of AI (1943-56)

- Warren McCulloch & Walter Pitts (1943): ANN with on-off neurons
  - Neurons triggered by sufficient #neighbors
  - Showed that any computable function computable with some network like this
  - Logical connectives implementable this way
  - Donald Hebb's 1949 learning rule
- Turing & Shannon chess programs, 1950s
- *SNARC*, first ANN computer, Minsky & Edmonds, 1951

Birth of AI...

- Dartmouth 1956 workshop for 2 months
  - Term "artificial intelligence"
  - Fathers of the field introduced
- *Logic Theorist*: program for proving theorems by Alan Newell & Herbert Simon

Early enthusiasm (1952-69)

- Claims: computers can do X
- *General Problem Solver*, Newell & Simon
  - Intentionally solved puzzles in a similar way as humans do (order of subgoals, etc)
- *Geometry Theorem Prover*, Herbert Gelernter, 1959
- Arthur Samuel's learning checkers program 1952
- LISP, time sharing, Advice taker: McCarthy 1958
- Integration, IQ geometry problems, algebra stories
- Blocks world: vision, learning, NLP, planning
- Adalines [Widrow & Hoff 1960], perceptron convergence theorem [Rosenblatt 1962]

A dose of reality (1966-74)

- Simple syntactic manipulation did not scale
  - ELIZA (example rule: if sentence contains "mother", then say: "tell me more about your family")
    - However, sometimes such bots (e.g. Julia) can fool humans
  - "the spirit is willing but the flesh is weak" -> "the vodka is good but the meat is rotten"
- Intractability
- Machine evolution did not scale
- *Perceptrons* book with negative result on representation capability of 1-layer ANNs [Minsky & Papert]

Knowledge-based systems (1969-79)

- *DENDRAL*: molecule structure identification [Feigenbaum et al.]
  - Knowledge intensive
- *Mycin*: medical diagnosis [Feigenbaum, Buchanan, Shortliffe]
  - 450 rules; knowledge from experts; no domain theory
  - Better than junior doctors
  - Certainty factors
- *PROSPECTOR*: drilling site choice [Duda et al]
- Domain knowledge in NLP
- Knowledge representation: logic, frames...

AI becomes an industry (1980-88)

- *R1*: first successful commercial expert system, configured computer systems at DEC; saved 40M$/year
- 1988: DEC had 40 expert systems, DuPont 100...
- 1981: Japan's 5th generation project
- Software tools for expert systems: Carnegie Group, Inference, Intellicorp, Teknowledge
- LISP-specific hardware: LISP Machines Inc, TI, Symbolics, Xerox
- Industry: few M$ in 1980 -> 2B$ in 1988

Return of ANNs (1986-)

- Mid-1980s, different research groups reinvented backpropagation (originally from 1969)
- Disillusionment on expert systems
- Fear of AI winter

Recent events (1987-)

- Rigorous theorems and experimental work rather than intuition
- Real-world applications rather than toy domains
- Building on existing work
  - E.g. speech recognition
    - Ad hoc, fragile methods in 1970s
    - Hidden Markov models now
  - E.g. planning (unified framework helped progress)
- Normative system design
  - Belief networks & probabilistic reasoning
  - Reinforcement learning
  - Multiagent systems
  - Resource-bounded reasoning