ARTIFICIAL INTELLIGENCE

2013 Semester 1
Chapter 1

Outline

- What is AI?
- A brief history
- The state of the art

What is AI?

- Creative extension of philosophy:
  - Understand and BUILD intelligent entities
- Origin after WWII
- Highly interdisciplinary
- Currently consist of huge variety of subfields
  - learning and perception
  - playing chess
  - proving mathematical theorems
  - writing poetry
  - diagnosing diseases
  - …

What is AI?

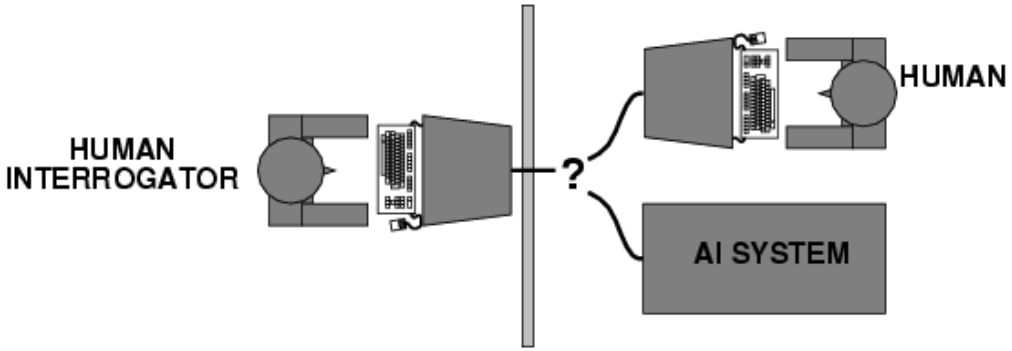
- Views of AI fall into four categories
- Different definitions due to different criteria
- Two dimensions:
  - Thought processes/reasoning vs. behavior/action
  - Success according to human standards vs. success according to an ideal concept of intelligence: rationality.
    - Human-centered approach => empirical science
    - Rationalist approach => combination of mathematics and engineering

Thinking humanly	Thinking rationally
Acting humanly	Acting rationally

- The textbook advocates "acting rationally"

Acting humanly: Turing Test

- Turing (1950) *Computing machinery and intelligence*
- "Can machines think?" → "Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game



- Suggested major components of AI: knowledge, reasoning, language understanding, learning

Thinking humanly: cognitive modeling

- 1960s "cognitive revolution": information-processing psychology
- Requires scientific theories of internal activities of the brain
- Both approaches (roughly, Cognitive Science and Cognitive Neuroscience) are now distinct from AI

Thinking rationally: "laws of thought"

- Aristotle: what are correct arguments/thought processes?
  - Correctness depends on irrefutability of reasoning processes
- This study initiated the field of logic.
  - The logicist tradition in AI hopes to create intelligent systems using logic programming.
- Several Greek schools developed various forms of *logic*: *notation* and *rules of derivation* for thoughts; may or may not have proceeded to the idea of mechanization
- Direct line through mathematics and philosophy to modern AI
- Problems
  - Not all intelligence is mediated by logic behavior
  - A big difference between "in principle" and "in practice"

Acting rationally: rational agent

- Rational behavior: doing the right thing
  - The right thing: that which is expected to maximize goal achievement, given the available information
- Doesn't necessarily involve thinking – e.g., blinking reflex
- Two advantages over previous approaches:
  - More general than law of thoughts approach
  - More amenable to scientific development.
- Limited rationality

Rational agents

- An agent is an entity that perceives and acts
- This course is about designing rational agents
- Abstractly, an agent is a function from percept histories to actions:

$$[f: P^* \rightarrow A]$$

- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- Caveat: computational limitations make perfect rationality unachievable

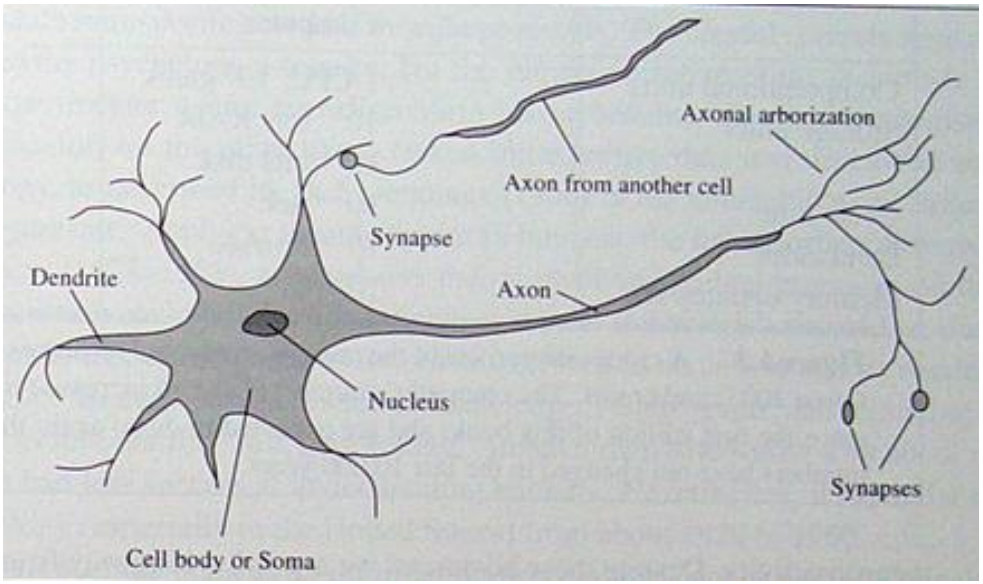
  → design best program for given machine resources

Foundations of AI

- Philosophy
  - Can formal rules be used to draw valid conclusions?
  - How does the mental mind arise from a physical brain?
  - Where does knowledge come from?
  - How does knowledge lead to action?
- Mathematics
  - What are the formal rules to draw valid conclusions?
  - What can be computed?
  - How do we reason with uncertain information?

Foundations of AI

- Neuroscience
  - How do brains process information?
    - a collection of simple cells can lead to thought, action, and consciousness



Foundations of AI

- Psychology
  - How do humans and animals think and act?
- Computer engineering
  - How can we build an efficient computer?
    - Molecular engineering
- Linguistics
  - How does language relate to thought?
    - Computational linguistics or natural language processing

Foundations of AI

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
Economics	utility, decision theory
Neuroscience	physical substrate for mental activity
Psychology	phenomena of perception and motor control, experimental techniques
Computer	building fast computers engineering
Control theory	design systems that maximize an objective function over time
Linguistics	knowledge representation, grammar

Abridged history of AI

1943	McCulloch & Pitts: Boolean circuit model of brain
1950	Turing's "Computing Machinery and Intelligence"
1956	Dartmouth meeting: "Artificial Intelligence" adopted
1952—69	Look, Ma, no hands!
1950s	Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
1965	Robinson's complete algorithm for logical reasoning
1966—73	AI discovers computational complexity Neural network research almost disappears
1969—79	Early development of knowledge-based systems
1980--	AI becomes an industry
1986--	Neural networks return to popularity
1987--	AI becomes a science
1995--	The emergence of intelligent agents

A brief history

- What happened after WWII?
  - 1943: Warren Mc Culloch and Walter Pitts: a model of artificial boolean neurons to perform computations.
    - Three sources
      - Knowledge of the basic physiology and function of neurons in the brain
      - A formal analysis of propositional logic
      - Turing's theory of computation
    - First steps toward connectionist computation and learning (Hebbian learning).
    - Marvin Minsky and Dann Edmonds (1951) constructed the first neural network computer
  - 1950: Alan Turing's "Computing Machinery and Intelligence"
    - First complete vision of AI.

A brief history (2)

- The birth of AI (1956)
  - Dartmouth Workshop bringing together top minds on automata theory, neural nets and the study of intelligence.
    - Allen Newell and Herbert Simon: The logic theorist (first nonnumerical thinking program used for theorem proving)
    - For the next 20 years the field was dominated by these participants.
  - Great expectations (1952-1969)
    - Newell and Simon introduced the General Problem Solver.
      - Imitation of human problem-solving
    - Arthur Samuel (1952-)investigated game playing (checkers) with great success.
    - John McCarthy(1958-) :
      - Inventor of Lisp (second-oldest high-level language)
      - Logic oriented, Advice Taker (separation between knowledge and reasoning)

A brief history (3)

- The birth of AI (1956)
  - Great expectations continued.
    - Marvin Minsky (1958 -)
      - Introduction of microworlds that appear to require intelligence to solve: e.g. blocks-world.
- Collapse in AI research (1966 - 1973)
  - Progress was slower than expected.
    - Unrealistic predictions.
    - Little or no knowledge of their subject matter.
      - e.g, machine translation
        - "the spirit is willing but the flesh is weak"
        - "the vodka is good but the meat is rotten"
  - Some systems lacked scalability.
    - Combinatorial explosion in search.
    - Microworlds (in principle) vs. real worlds (in practice)
  - Fundamental limitations on techniques and representations.
    - Minsky and Papert (1969) Perceptrons.

A brief history (4)

- AI revival through knowledge-based systems (1969-1970)
  - General-purpose vs. domain specific
    - E.g. the DENDRAL project (Buchanan et al. 1969)
      - First successful knowledge intensive system.
  - Expert systems
    - MYCIN to diagnose blood infections (Feigenbaum et al.)
      - Introduction of uncertainty in reasoning.
  - Increase in knowledge representation research.
    - Logic, frames, semantic nets, …

A brief history (5)

- AI becomes an industry (1980 - present)
  - R1 at DEC (McDermott, 1982)
  - Fifth generation project in Japan (1981)
- Puts an end to the AI winter.
- Connectionist revival (1986 - present)
  - Parallel distributed processing (RumelHart and McClelland, 1986); back-propagation learning algorithm.

A brief history (6)

- AI becomes a science (1987 - present)
  - Neats vs. scruffies.
    - In speech recognition: hidden markov models
    - In neural networks
    - In uncertain reasoning and expert systems: Bayesian network formalism
    - …
- The emergence of intelligent agents (1995 - present)
  - The whole agent problem:

    "How does an agent act/behave embedded in real environments with continuous sensory inputs"

State of the art (1)

- Deep Blue defeated the reigning world chess champion Garry Kasparov in 1997
- Proved a mathematical conjecture (Robbins conjecture) unsolved for decades
- No hands across America (driving autonomously 98% of the time from Pittsburgh to San Diego)
- During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program that involved up to 50,000 vehicles, cargo, and people
- NASA's on-board autonomous planning program controlled the scheduling of operations for a spacecraft
- Proverb solves crossword puzzles better than most humans

State of the art (2)

- The Air Operations Division, AOD
  - uses for the rule based expert systems.
  - has use for artificial intelligence for surrogate operators for combat and training simulators, mission management aids, support systems for tactical decision making, and post processing of the simulator data into symbolic summaries.
- The Artificial Intelligence supported Design of Aircraft, AIDA
  - is used to help designers in the process of creating conceptual designs of aircraft.
- The Integrated Vehicle Health Management system
  - An aircraft must process and interpret data taken from the various sensors on the aircraft.
  - The system needs to be able to determine the structural integrity of the aircraft.

State of the art (3)

- The Intelligent Flight Control System
  - could enable a damaged aircraft to continue flight until a safe landing zone can be reached.
  - was tested on an F-15
  - compensates for all the damaged components by relying on the undamaged components.

Other fields in which AI methods are implemented – borrowed from wikipedia

- Artificial life
- Automated reasoning
- Automation
- Data mining
- Knowledge representation
- Semantic Web
- Robotics
- Intelligent agent
- Intelligent control

Other fields in which AI methods are implemented – borrowed from wikipedia

- Artificial life
  - is a field of study and an associated art form which examine systems related to life, its processes, and its evolution through simulations using computer models, robotics, and biochemistry.
  - studies the logic of living systems in artificial environments.
  - imitates traditional biology by trying to recreate biological phenomena.
- Automated reasoning
- Automation
  - is the use of control systems and information technologies to reduce the need for human work in the production of goods and services.
  - The main advantages of automation are:
    - Replacing human operators in tasks that involve hard physical or monotonous work.
    - Replacing humans in tasks done in dangerous environments (i.e. fire, space, volcanoes, nuclear facilities, underwater, etc.)
    - Performing tasks that are beyond human capabilities of size, weight, speed, endurance, etc.
    - Economy improvement.

Other fields in which AI methods are implemented – borrowed from wikipedia

- Data mining
  - is the process of extracting patterns from large data sets by combining methods from statistics and artificial intelligence with database management.
  - is seen as an increasingly important tool by modern business to transform data into business intelligence giving an informational advantage.
- Knowledge representation and reasoning
  - is an area of artificial intelligence whose fundamental goal is to represent knowledge in a manner that facilitates inferencing (i.e. drawing conclusions) from knowledge.
  - analyzes how to formally think - how to use a symbol system to represent a domain of discourse (that which can be talked about), along with functions that allow inference (formalized reasoning) about the objects.

Other fields in which AI methods are implemented – borrowed from wikipedia

- Semantic Web
  - is a "web of data" that enables machines to understand the semantics, or meaning, of information on the World Wide Web.
  - extends the network of hyperlinked human-readable web pages by inserting machine-readable metadata about pages and how they are related to each other, enabling automated agents to access the Web more intelligently and perform tasks on behalf of users.
- Robot
  - is a virtual or mechanical artificial agent.

Other fields in which AI methods are implemented – borrowed from wikipedia

- Intelligent agent
  - is an autonomous entity which observes and acts upon an environment and directs its activity towards achieving goals.
  - may also learn or use knowledge to achieve their goals.
- Intelligent control
  - is a class of control techniques, that use various AI computing approaches like neural networks, Bayesian probability, fuzzy logic, machine learning, evolutionary computation and genetic algorithms.