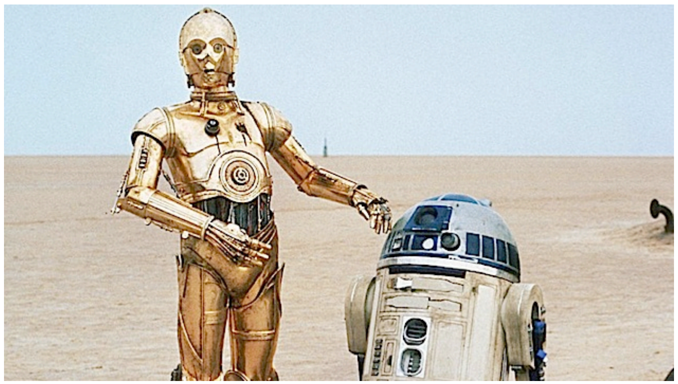
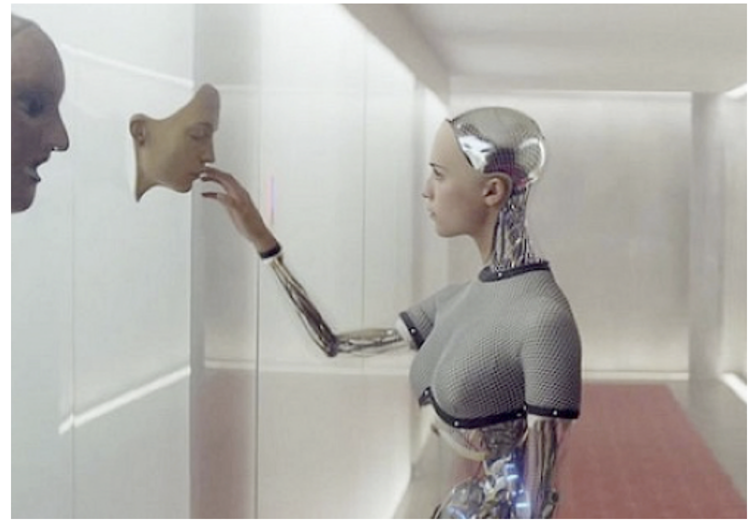
Artificial Intelligence
CS 534

Week 1

What is AI?





What is AI? Quoting AI pioneers

"*... the ability to solve hard problems.*" M. Minsky

"... in any real situation behavior appropriate to the ends of the system and adaptive to the demands of the environment can occur, within some limits of speed and complexity." A. Newell and H. A. Simon

"*Intelligence means getting better over time." R.* Schank

"Intelligence is the power to rapidly find an adequate solution in what appears a priori (to observers) to be an immense search space."
D. Lenat and E. Feigenbaum

"*AI is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable. Intelligence is the computational part of the ability to achieve goals in the world. Varying kinds and degrees of intelligence occur in people, many animals and some machines."*
J. McCarthy

What is AI? (NOT!)

“*An attempt to write programs to duplicate with a machine the natural unintelligence of the programmer*.”

“*An area of computer science that follows the credo, "When in doubt, use a graph search!!*"

“*A subfield of computer science devoted to the construction of extremely complex programs that do not work*.

More advanced definition (requires some thinking):

“*AI is, by definition, things we can't do. Once we solve a problem, it is no longer AI. Once upon a time, the concept of a compiler was considered an AI project; once it was actually done, not so.*

<u>Corollary:</u> there are no solvable AI problems.”

Course facts

- **When**:
  - 6:00 pm - 8:50 pm, Mon (Fall semester)
- **Where**: Room HL 116
- **Who**: Dr. Dmitry Korkin, Associate Professor

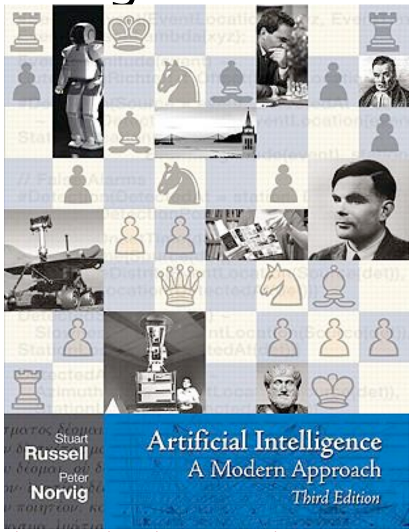
  Mr. Suhas Srinivasan, TA

- **Office**: BL22 @ Fuller Labs
- **Email**: dkorkin@wpi.edu
  - Note: Email is the best way to reach me to make appointments or ask questions.
  - Be persistent: if I don't reply the same day, try again!

Course facts (contd.)

- **Office Hours:**
  - 4:00 pm – 5:00 pm (Mon) @ BL22
  - Please let me know when you will come for an office hour
  - TA office hours: TBA

- **Textbook and other materials:**
  - Stuart J. Russell and Peter Norvig. “Artificial Intelligence: A Modern Approach” (3rd Edition)
  - Lecture materials: Note that the textbook and lecture materials are OFTEN complementary!
  - Scientific papers



Course goals

- Students will acquire knowledge on the concepts and problems from classical as well as state-of-the-art areas of AI

- Students will develop a deeper understanding of some of the most important methods and algorithms in AI

- Students will learn how to critically read and peer-review scientific publications from the leading AI journals and conferences

- Students will learn to work in a team and jointly apply their skills to solve real-world problems

Units: Topics covered

1. Introduction & History
   A. History of AI
   B. Intelligent agents

Units: Topics covered

1. Introduction & History (2 classes)
   A. History of AI
   B. Intelligent agents

2. Searching (2 classes)
   A. Classical search algorithm for problem solving
   B. Advanced search algorithms. Adversarial search. Constraint satisfaction

Units: Topics covered

1. Introduction & History (2 classes)
   A. History of AI
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2. Searching (2 classes)
   A. Classical search algorithm for problem solving
   B. Advanced search algorithms. Adversarial search. Constraint satisfaction

3. Reasoning with logical agents (2 classes)
   A. Logical agent. Propositional logic
   B. First-order logic

Units: Topics covered (contd.)

4. Learning (3 classes)
    A. Basic principles. Unsupervised Learning
    B. Supervised learning
    C. Deep learning. Reinforcement learning

5. Probabilistic Reasoning (2 classes)
    A. Graphical models

6. Natural language processing (1 class)
    A. Basics of NLP. Grammars. Applications

What will not be included

1. Knowledge representation and planning
2. Agent-based modeling
3. Making complex decisions
4. Game theory
5. Image processing and recognition
6. Robotics

Expanded class structure (tentative)

Units:

Unit 1: Introduction & History: Aug 27, Sep 10
Unit 2: Searching: Sept 10 (A1R), Sept 17 (A1D, A2R)
Unit 3: Logical Reasoning: Sept 24 (A2D, A3R), Oct 1, Oct 9 (M1)
Unit 4: Learning: Oct 16 (A3D, A4R), Oct 22, Oct 29
Unit 5: Probabilistic Reasoning: Nov 5 (A4D, A5R, GS), Nov 12
Unit 6: Intro to Natural language processing: Nov 19 (A5D), Nov 26 (M2)
Project presentations: Dec 3 (FE), Dec 10

M: Midterm
GS: Group session for project discussion
AR: Assignment released
(Example: A1R – Assignment 1 is released during this lecture)
AD: assignment due
(Example: A1D – Assignment 1 is due that day, **before** the lecture)
FE: Full-term evaluation

A typical class structure

- Review questions for the class
- Theory and tools background
- Trivia

Course research project

- A project can be
  - An application of AI methods and tools to a specific problem in the area of student team's interest (common)
  - Comparative analysis of AI methods using an important dataset (less common)
- Student team = ~3 students
- Projects will be evaluated for its four parts:
  - **Project proposal**
  - Beta version
  - Final version
  - Presentation
  - Feel free to send me a version of your paper before the deadline for some feedback
  - We will have an in-class project group discussion session
- I will provide you with a suggested project timeline in a few lectures

Course project proposal

- Project proposal should include the following
  - Project tittle
  - Problem description (1 paragraph)
  - Significance/importance of the problem supported by the literature (1 par.)
  - Proposed AI methodology (general, non-technical description, but well thought-through, 1 par.)
  - The data sources that will be used (1 par.)
- Total size ¾-1 page
- Topic ideas
  - Searching or learning on real-world large-scale data: social networks, weather, economic, commercial, etc.
  - Text mining social networks or newspapers for specific information
  - Comparison of state-of-the-art methods
  - Games, e.g. board games, card games, etc.
  - Image, video, sound processing or analysis
  - Beat the Turing test

Important dates (tentative schedule)

- Sep. 3: Deadline to report a “NO group” membership
- Sep. 7: Deadline to form groups and select the title/topic of project. Report to me
- Sep. 17: Assignment 1 is due
- Sep. 17: Submit project proposal. Report to me
- Sep. 24: Assignment 2 is due
- Sep. 24: Proposals are returned to the teams
- Oct. 8: Midterm 1
- Oct. 16: Assignment 3 is due
- Nov. 5: Assignment 4 is due
- Nov. 19: Assignment 5 is due
- Nov. 26: Midterm 2
- Dec 4: Beta version of course project paper is due. Report to me
- Dec 13: Final version of course project paper is due. Report to me

Grading

- Assignments: 5 x 80 pts = 400 pts
- Midterms: 2 x 150 pts=300 pts
- Project presentation: 75 pts
- Project presentation:
  - Proposal: 50 pts
  - Beta version: 100 pts
  - Final version: 75 pts
- <u>Total</u>: 1,000 possible pts

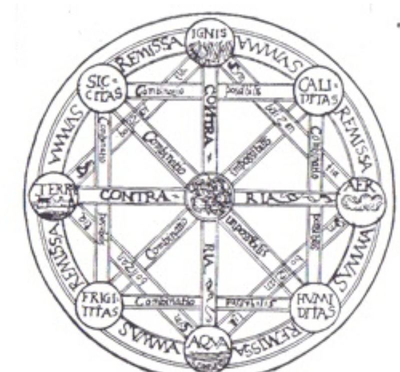
Action items

- Start forming a project group. If by Sep. 3 you are not a part of a group, report to me and I will assign you to one
  - Use discussion board to attract members or seek for a group

- By Sep. 7 each group should select the title/topic (1 sentence) of its project and email to me along with the list of group members for approval

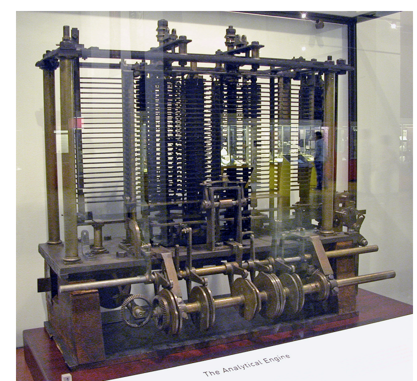
History of AI.
Part I: Pre-AI cornerstones

- Automatons: Realistic humanoid automatons were built by craftsmen from every civilization, including Yan Shi, Hero of Alexandria, Al-Jazari and Wolfgang von Kempelen. The oldest known automatons were the sacred statues of ancient Egypt and Greece



Leibniz' diagram

- Formal reasoning: Artificial intelligence is based on the assumption that the process of human thought can be mechanized. From the 13th century, scientists developed logical machines devoted to the production of knowledge by logical means

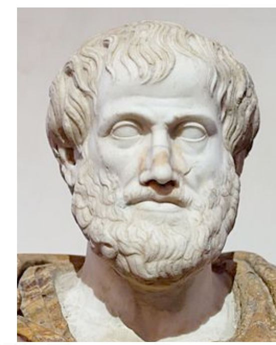


Analytical Engine, by Babbage

- Computer science: Calculating machines were built in antiquity and improved throughout history by many mathematicians, from Leibniz and Babbage to Turing and von Neumann.

History of AI. Part I: Pre-AI

- 2,000-1,000 BC: Greek myths of Hephaestus and Pygmalion incorporated the idea of intelligent robots, such as Talos a giant automaton made of bronze to protect Europa in Crete from pirates and invaders

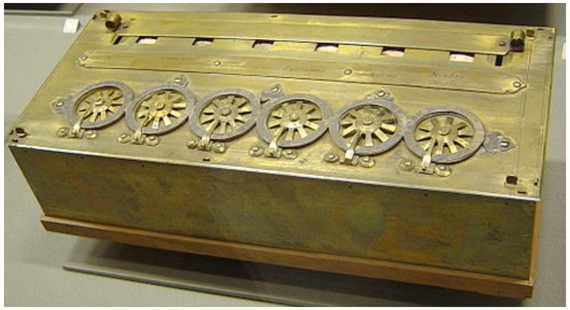


- 384 BC–322 BC: Aristotle described the syllogism, a method of formal, mechanical thought (basic logical reasoning)

- 1st century: Heron of Alexandria created mechanical men and other automata

History of AI. Part I: Pre-AI

- Early 17th century: René Descartes proposed that bodies of animals are nothing more than complex machines (but that mental phenomena are of a different "substance")

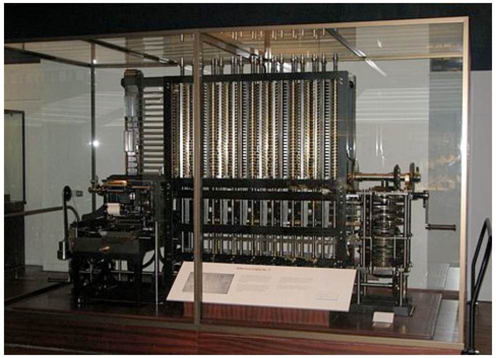


- 1642: Blaise Pascal invented the mechanical calculator the first digital calculating machine

- 1672: Gottfried Leibniz invented the binary numeral system and envisioned a universal calculus of reasoning (alphabet of human thought) by which arguments could be decided mechanically. It was a precursor to computational linguistics.

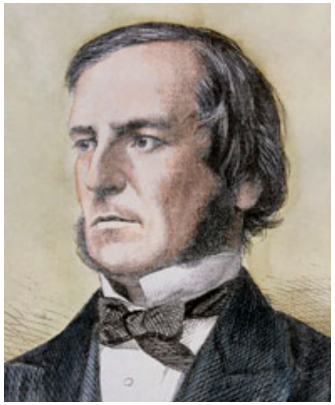
History of AI. Part I: Pre-AI

- 1837: Mathematician Bernard Bolzano made the first modern attempt to formalize semantics



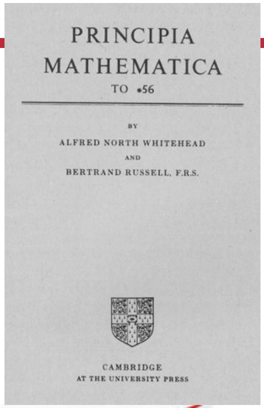
- 1822-1859: Charles Babbage & Ada Lovelace worked on programmable mechanical calculating machines

- 1854: George Boole set out to "investigate the fundamental laws of those operations of the mind by which reasoning is performed, to give expression to them in the symbolic language of a calculus", inventing Boolean algebra



History of AI. Part II: XX century

- 1910: Bertrand Russell and Alfred North Whitehead published *Principia Mathematica*, which revolutionized formal logic

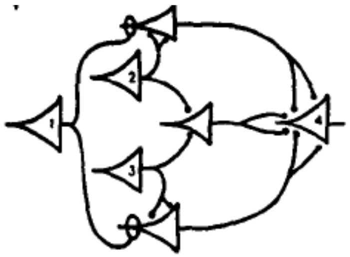


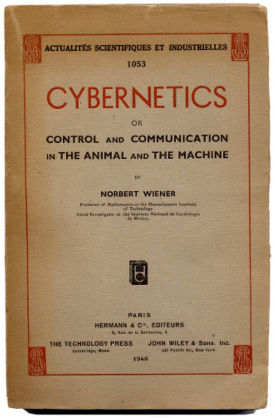
- 1923: Karel Čapek's play *R.U.R.* (Rossum's Universal Robots) opened in London. This is the first use of the word "robot"

- 1931: Kurt Gödel, father of theoretical computer science, built a universal, integer-based programming language for his Incompleteness Theorem and introduced Gödel fuzzy logic

History of AI. Part II: XX century

- 1943: McCulloch and Pitts publish "A Logical Calculus of the Ideas Immanent in Nervous Activity”, laying foundations for artificial neural networks

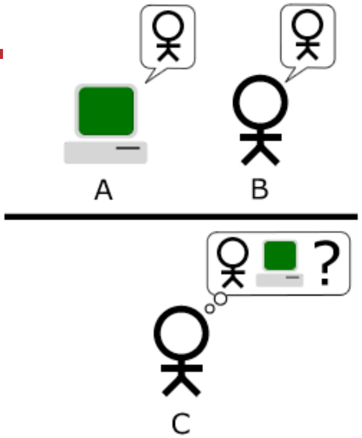




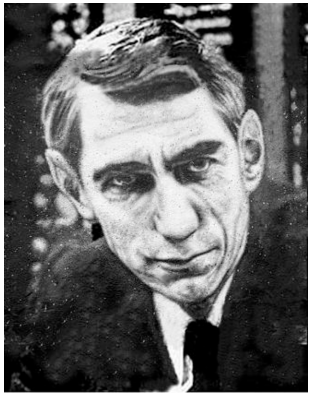
- 1943: Arturo Rosenblueth, Norbert Wiener and Julian Bigelow coin the term "cybernetics”

- 1945: Game theory which would prove invaluable in the progress of AI was introduced in paper “Theory of Games and Economic Behavior” by mathematician von Neumann and economist Morgenstern

History of AI. Part III: Birth of AI



- 1950: Alan Turing proposed the Turing Test as a measure of machine intelligence:

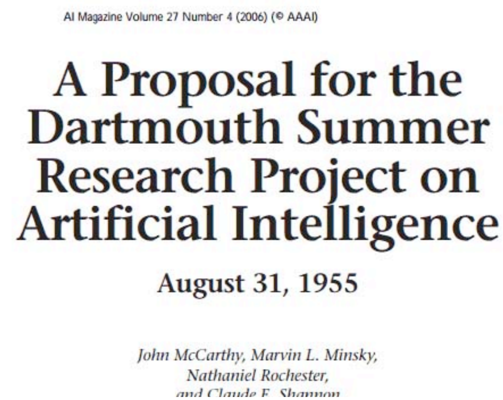


- 1950: Claude Shannon published a detailed analysis of chess playing as search

- 1951: The 1st working AI programs were written to run on the Ferranti Mark 1 machine: a checkers-playing and a chess-playing programs

History of AI. Part III: Birth of AI

- 1956: The name artificial intelligence is used for the first time as the topic of the second Dartmouth Conference, organized by John McCarthy



AI Magazine Volume 27 Number 4 (2006) (© AAAI)

A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence

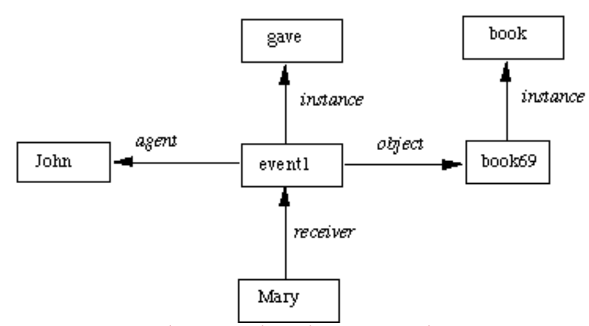
August 31, 1955

John McCarthy, Marvin L. Minsky, Nathaniel Rochester, and Claude E. Shannon

- 1959: John McCarthy and Marvin Minsky founded the MIT AI Lab

CSAIL

- Late 1950s: Margaret Masterman and colleagues at University of Cambridge designed semantic nets for machine translation.



History of AI. Part IV: Golden years

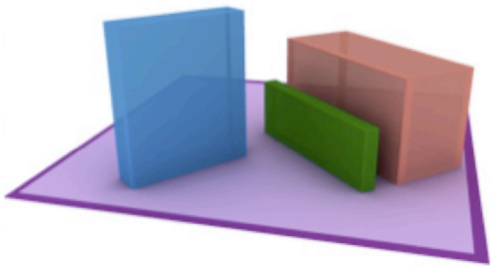
- Reasoning as search: The first AI programs relied on the same algorithm—they proceeded step by step towards it as if searching through a maze, backtracking whenever they reached a dead end. Newell and Simon tried to capture a general version of this algorithm in a program called the "General Problem Solver”

- Natural language processing (NLP): allowing computers to communicate in natural languages like English. An early success was Daniel Bobrow's program STUDENT, which could solve high school algebra word problems. Joseph Weizenbaum's ELIZA could carry out conversations that were very realistic. But in fact it simply repeated what was said to her, rephrasing her response with a few grammar rules

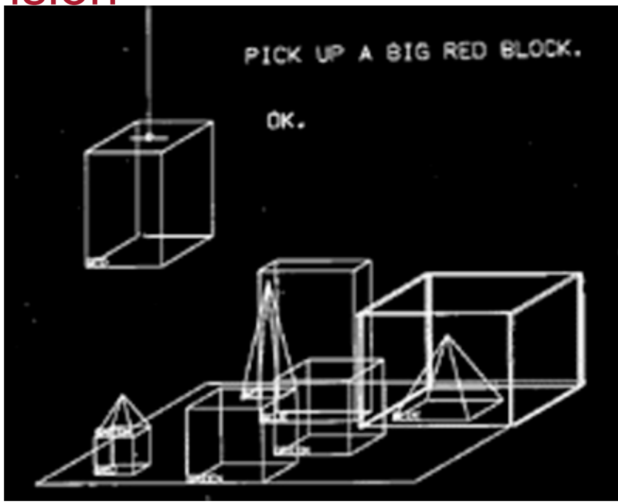
History of AI. Part IV: Golden years

Micro-worlds:

- Was introduced by Minsky and Papert: AI research should focus on artificially simple situations



- Many researchers focused on "blocks world," which consists of colored blocks of various shapes and sizes arrayed on a flat surface
- This paradigm led to innovative work in machine vision and invention of constraint propagation



- The biggest achievement: Terry Winograd's SHRDLU. It could communicate in ordinary English sentences, plan operations and execute them

The optimism

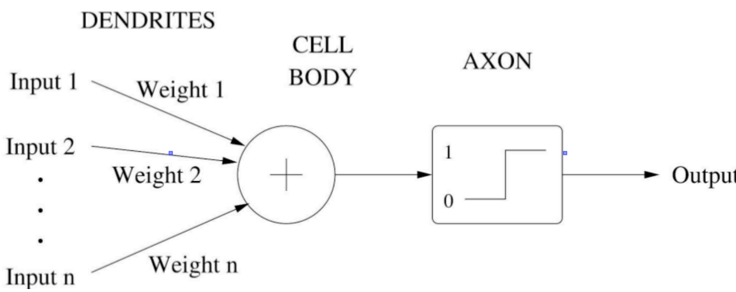
- 1958: H. A. Simon and Allen Newell: "within ten years a digital computer will be the world's chess champion" and "within ten years a digital computer will discover and prove an important new mathematical theorem."
- 1965: H. A. Simon: "machines will be capable, within twenty years, of doing any work a man can do."
- 1967: Marvin Minsky: "Within a generation ... the problem of creating 'artificial intelligence' will substantially be solved."
- 1970: Marvin Minsky (in Life Magazine): "In from three to eight years we will have a machine with the general intelligence of an average human being.

The problems

- Limited computer power:
  - As of 2011, practical computer vision applications require 10,000 to 1,000,000 MIPS. By comparison, the fastest supercomputer in 1976, Cray-1 (retailing at $5 million to $8 million), was only capable of around 80 to 130 MIPS, and a typical desktop computer at the time achieved less than 1 MIPS.
- Intractability and the combinatorial explosion:
  - Richard Karp: there are many problems that would probably only be solved in exponential time (NP-completeness).
  - Thus, many of the toy solutions in AI would never scale up to the real-world problems
- Commonsense knowledge and reasoning: vision or natural language required enormous amounts of information about the world (Big Data), which was not feasible in 1970s
- Moravec's paradox: contrary to traditional assumptions, high-level reasoning (e.g., theorem proving) requires very little computation, but low-level sensorimotor skills (crossing a room with obstacles) requires enormous computational resources

History of AI. Part V: AI Winter

- British government, DARPA, and NRC became frustrated with the lack of progress in AI
- By 1974, funding for AI projects was hard to find
- Dark age of connectionism:
  - A perceptron was a form of neural network introduced in 1958 by Frank Rosenblatt
  - The research on perceptrons came to a sudden halt with the publication of Minsky and Papert's 1969 book Perceptrons
  - Virtually no research at all was done in connectionism for 10 years
  - Rosenblatt would not live to see the field’s revival



History of AI. Part VI: Boom (1980s)

- The rise of expert systems:
  - 1971-74: Feigenbaum and Lederberg: DENDRAL, an AI expert system to help organic chemists in identifying unknown organic molecules, by analyzing their mass spectra and using knowledge of chemistry

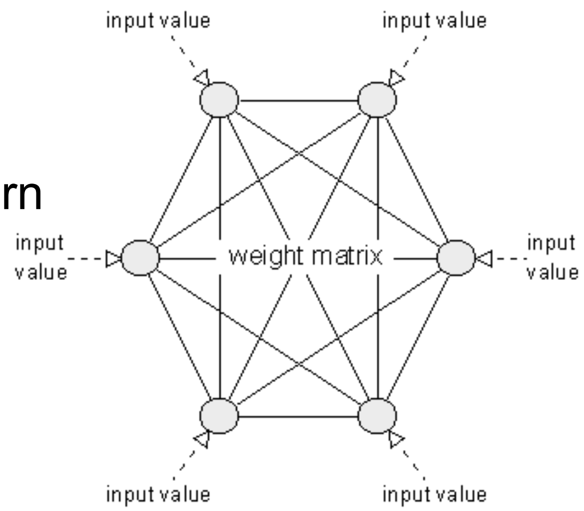
- 1980s: Japanese government aggressively funded AI with its fifth generation computer project, running PROLOG

- Knowledge based systems and knowledge engineering became a major focus of AI research in the 1980s

- 1982: R1 (XCON): First commercial expert system, developed at Digital Equipment Corporation
  - Configured orders for new computer systems
  - By 1986 was saving the company $40M a year

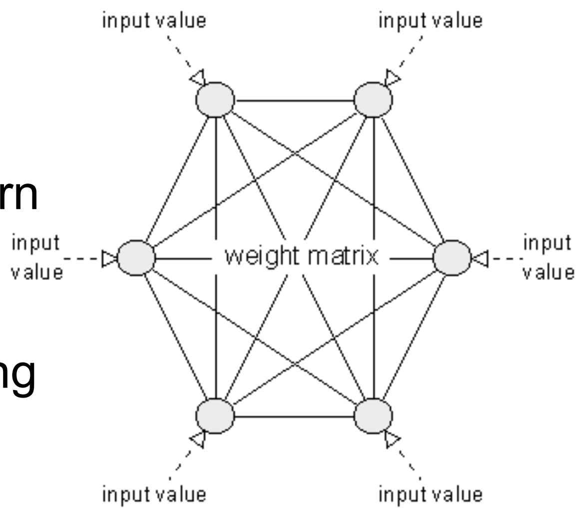
History of AI. Part VI: Boom (1980s)

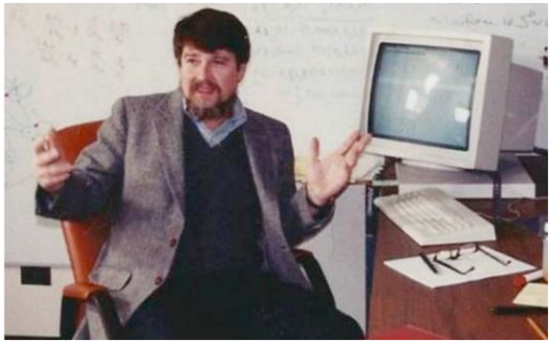
- The revival of connectionism:
  - 1982: John Hopfield was able to prove that a form of neural network (now called a "Hopfield net") could learn and process information in a completely new way



History of AI. Part VI: Boom (1980s)

- The revival of connectionism:
  - 1982: John Hopfield was able to prove that a form of neural network (now called a "Hopfield net") could learn and process information in a completely new way
  - David Rumelhart popularized a new method for training neural networks called "backpropagation" (discovered years earlier by Paul Werbos)
  - Neural networks would become commercially successful in the 1990s, when they began to be used as the engines driving programs like optical character recognition and speech recognition





History of AI. Part VII: Second AI Winter

- 1987–1993: AI rose and fell in a classic pattern of an economic bubble
- 1987: Sudden collapse of the market for specialized AI hardware
- 1987: Apple and IBM are cheaper and more popular than LISP computers
- Late 1980s: New leadership at DARPA had decided that AI was not "the next wave”
- 1991: The impressive list of goals penned in 1981 for Japan's Fifth Generation Project had not been met

History of AI. Part VIII: 1993-preent

- 1997: Deep Blue became the first computer chess-playing system to beat a reigning world chess champion

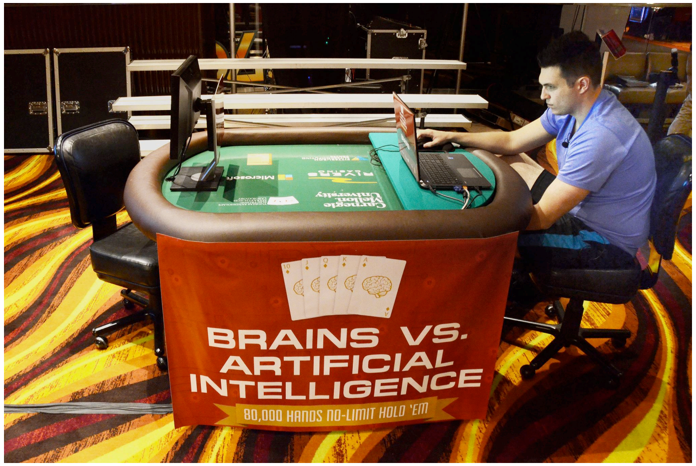
- 2005: A Stanford robot won the DARPA Grand Challenge by driving autonomously for 131 miles along an unrehearsed desert trail

- 2007: A team from CMU won the DARPA Urban Challenge by autonomously navigating 55 miles in an Urban environment while adhering to traffic hazards and all traffic laws

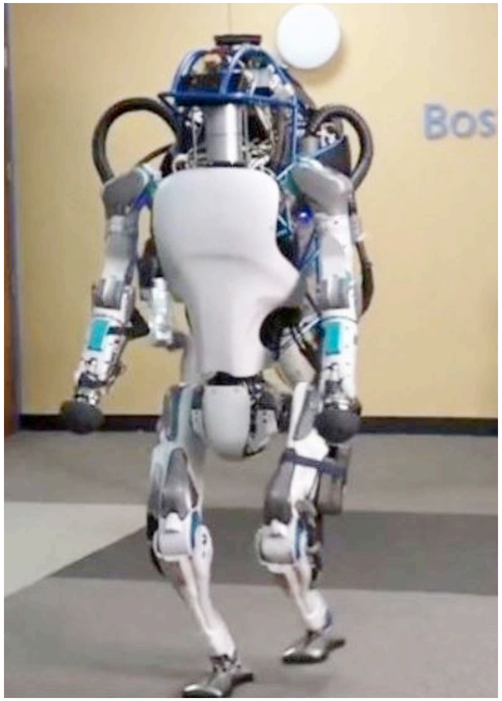
- 2011: In a Jeopardy! quiz show exhibition match, IBM's question answering system, Watson, defeated the two greatest Jeopardy! champions

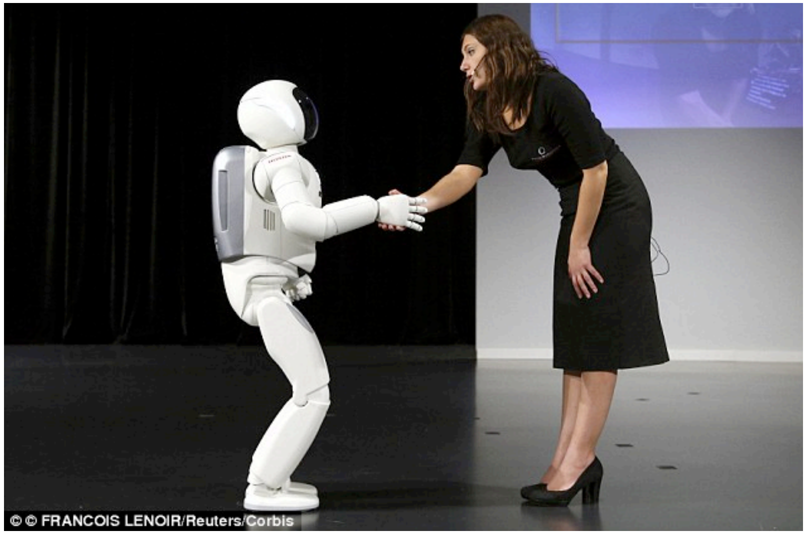
- 2016: Google's AlphaGo: the first time a computer Go program has beaten a 9-dan professional in 5 games

The role of AI nowadays: AI in Games

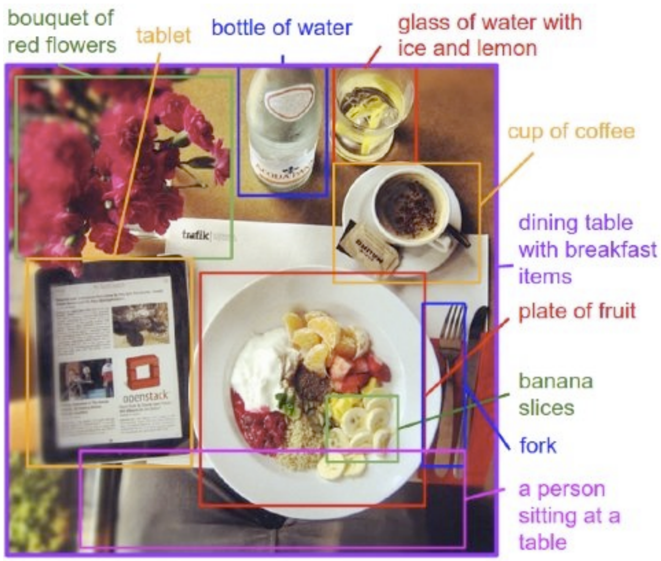


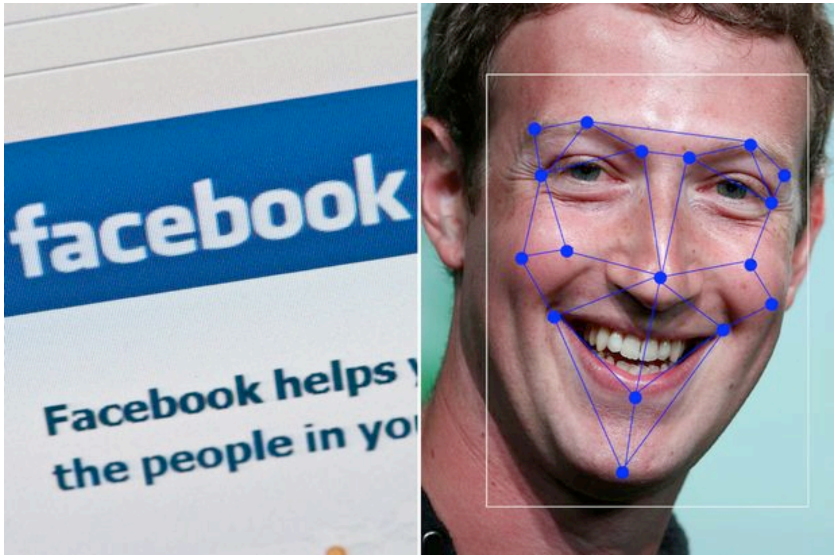
The role of AI nowadays: AI in Robotics



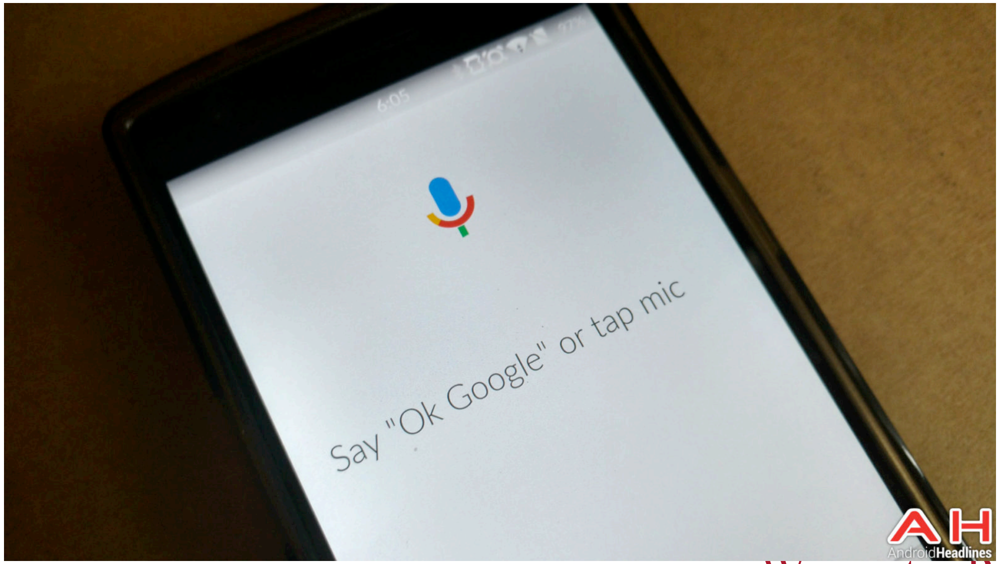


The role of AI nowadays: AI in Image recognition





The role of AI nowadays: AI in Speech processing



Questions before the break?

Introduction: Intelligent Agents

Textbook chapters to read

- Chapter 2
- Chapter 3 (Sections 3.1- 3.4)
- Appendix A: O() notation, NP-hard and NP-complete problems

Intelligent Agents

Let's define an intelligent agent…

Intelligent Agents

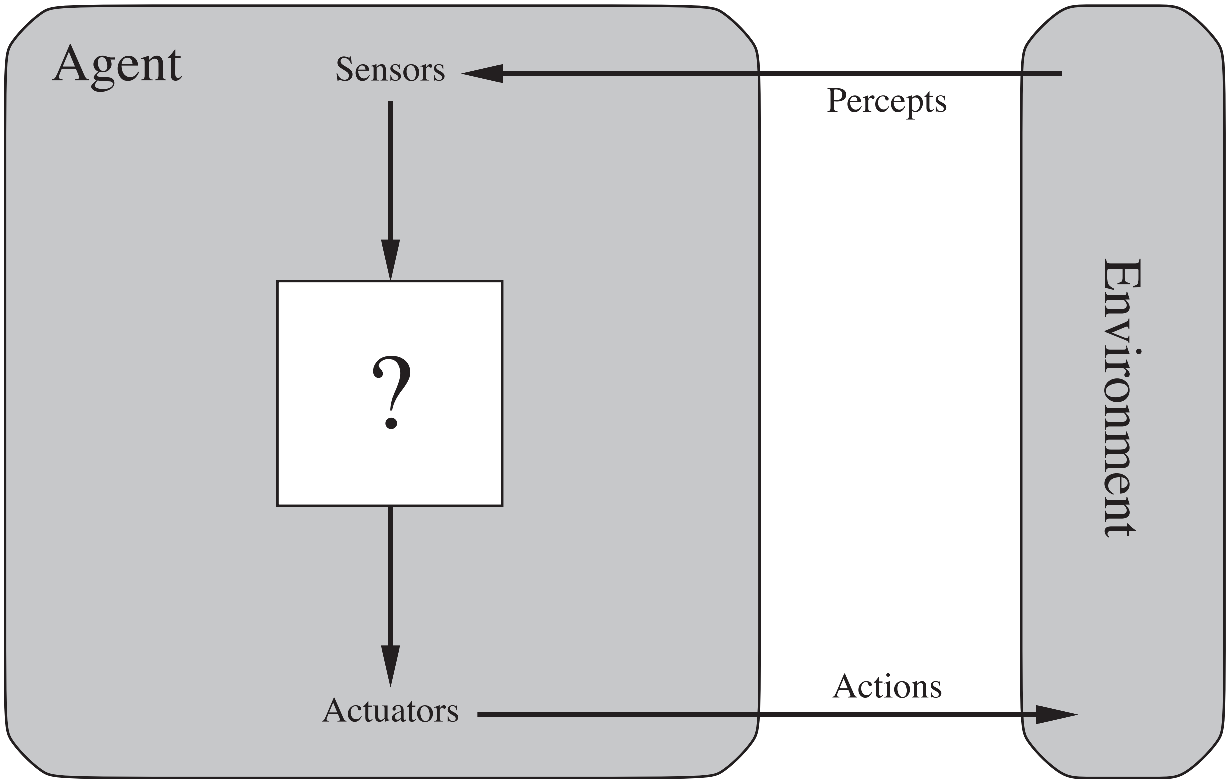
Well, a different kind of agent…

Intelligent Agents

Intelligent agent:

- Can perceive the state of the environment through its sensors
- Can act upon its states through its actuators
- Has a function that maps sensors to actuators, called the control policy for the agent
- Decisions on which actuators to carry out based on the sensors are repeated in the loop
- The whole process is called Perception-Effect Cycle

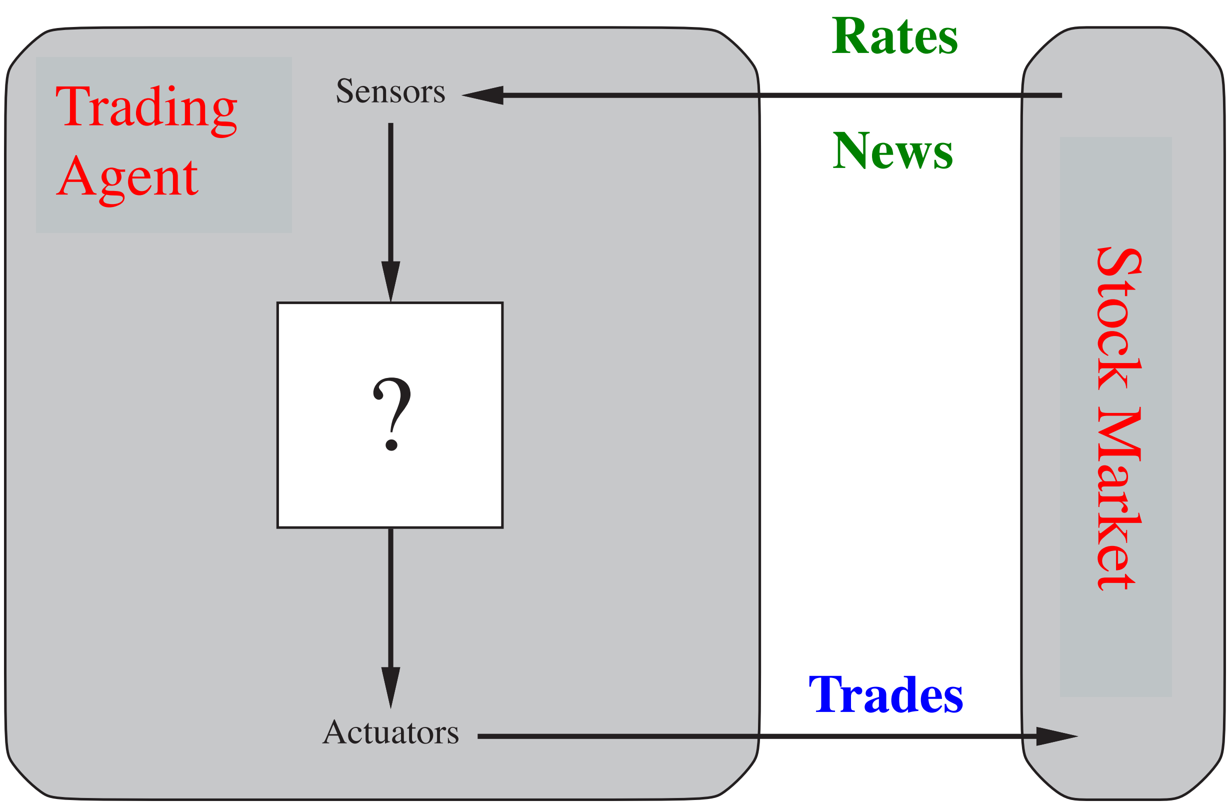
Perception-Effect Cycle



Example: AI in finance

Trading agent:

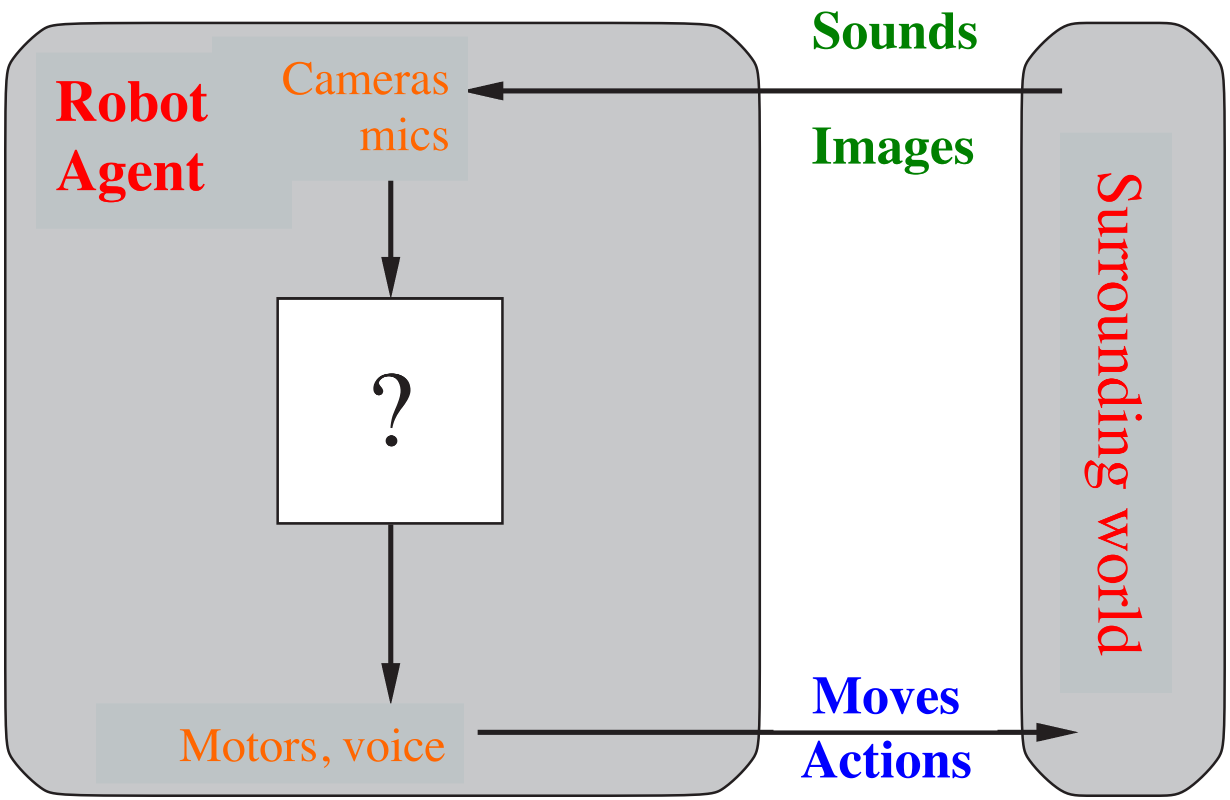
- Making trading decisions



Example: AI in robotics

Robot agent:

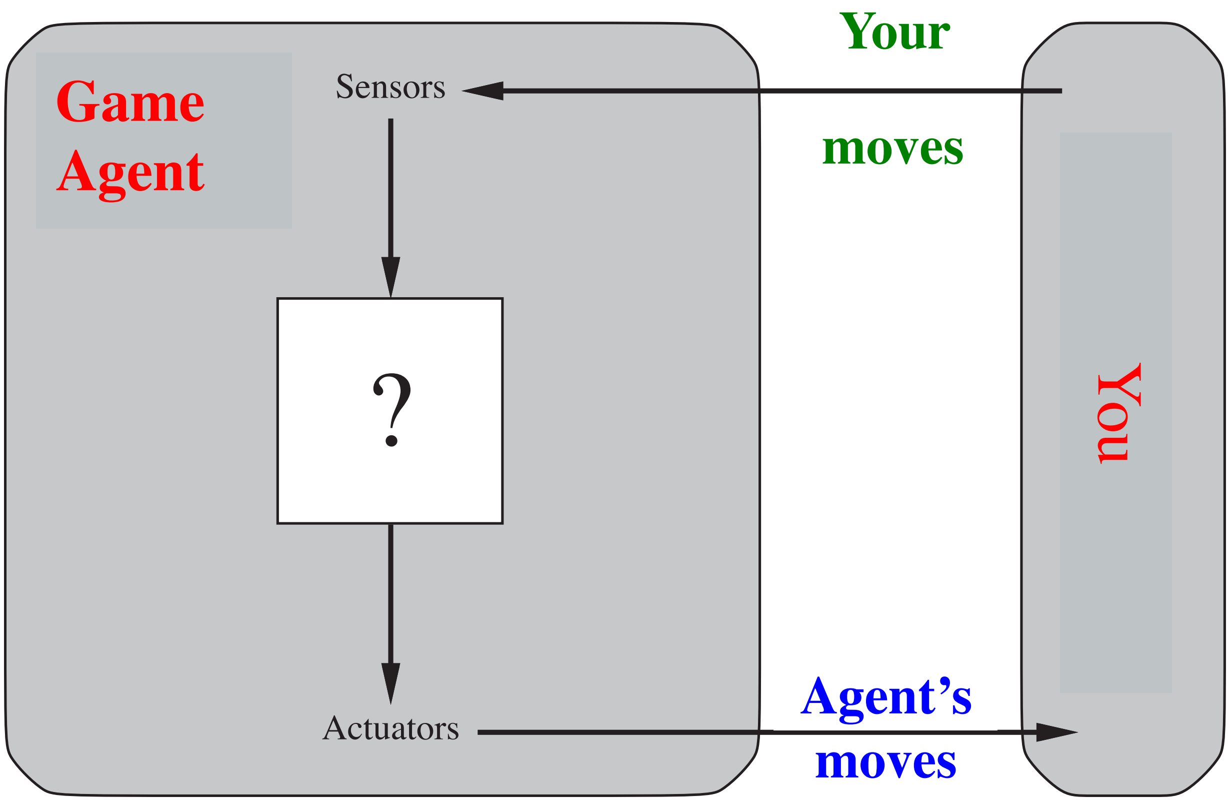
- Interacting with the world around it



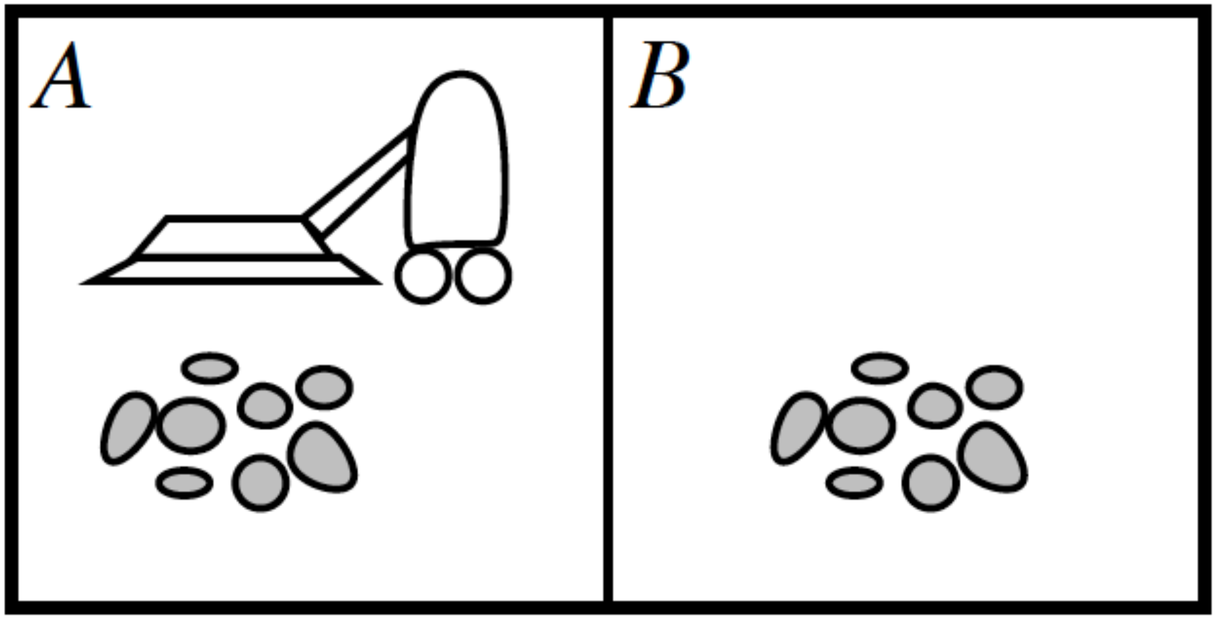
Example: AI in games

Game agent:

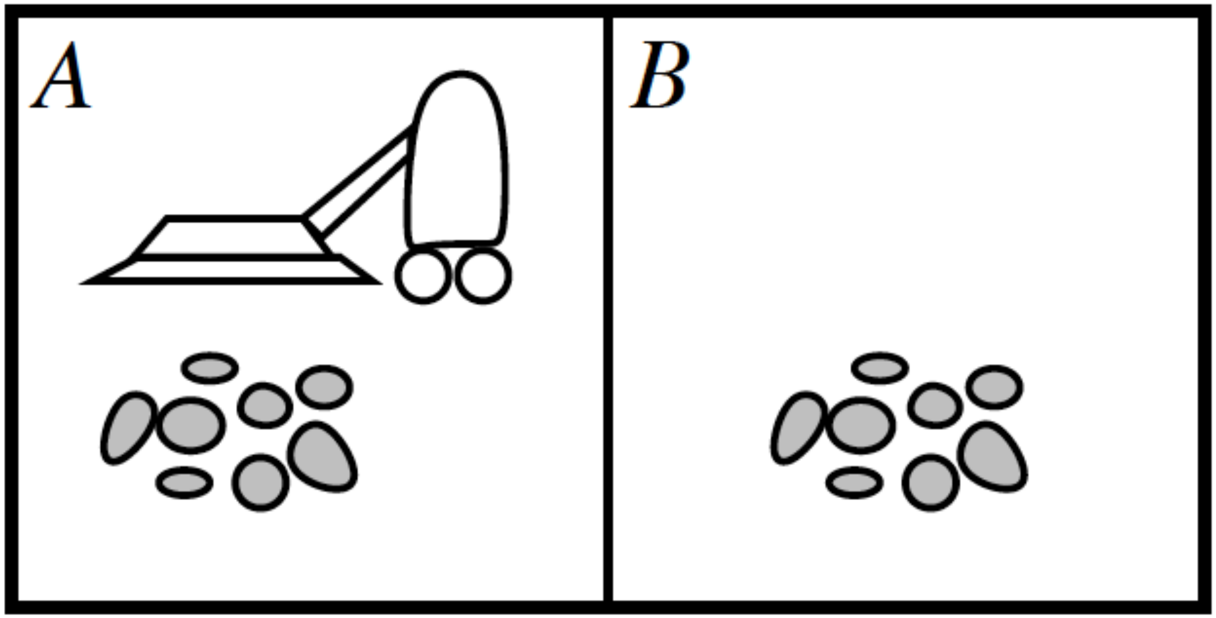
- Interacting with the world around it



Vacuum world



Vacuum world



Percepts: location and contents, e.g., $[A, Dirty]$

Actions: $Left$, $Right$, $Suck$, $NoOp$

A vacuum-cleaner agent: Function table

Percept sequence	Action
$[A, Clean]$	$Right$
$[A, Dirty]$	$Suck$
$[B, Clean]$	$Left$
$[B, Dirty]$	$Suck$
$[A, Clean], [A, Clean]$	$Right$
$[A, Clean], [A, Dirty]$	$Suck$
$\vdots$	$\vdots$

A vacuum-cleaner agent: Function table

Percept sequence	Action
$[A, Clean]$	$Right$
$[A, Dirty]$	$Suck$
$[B, Clean]$	$Left$
$[B, Dirty]$	$Suck$
$[A, Clean]$, $[A, Clean]$	$Right$
$[A, Clean]$, $[A, Dirty]$	$Suck$
$\vdots$	$\vdots$

function REFLEX-VACUUM-AGENT([*location*,*status*]) **returns** an action

    if *status* = *Dirty* **then return** *Suck*
    else if *location* = *A* **then return** *Right*
    else if *location* = *B* **then return** *Left*

A vacuum-cleaner agent

Percept sequence	Action
$[A, Clean]$	$Right$
$[A, Dirty]$	$Suck$
$[B, Clean]$	$Left$
$[B, Dirty]$	$Suck$
$[A, Clean], [A, Clean]$	$Right$
$[A, Clean], [A, Dirty]$	$Suck$
⋮	⋮

function REFLEX-VACUUM-AGENT([*location*,*status*]) **returns** an action

if *status* = *Dirty* **then return** *Suck*
else if *location* = *A* **then return** *Right*
else if *location* = *B* **then return** *Left*

Define it

Implement it

The idea of Rationality

- Intuition: Rational agent = the agent that does the right things, *i.e.*, the Function table is filled correctly

- How to quantify the right things? Using performance measure!

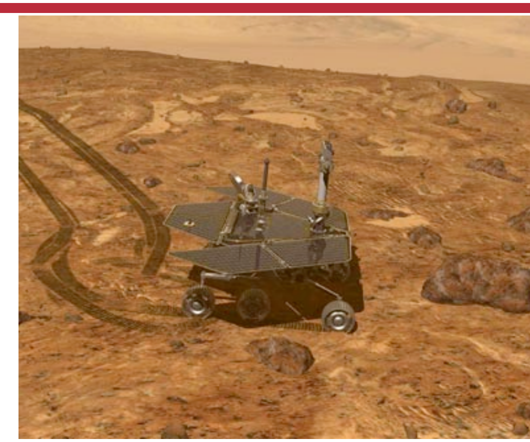
- Fixed performance measure evaluates the environment sequence, *i.e.*, sequence of environment states
  - Not agent states! An agent can delude itself that it does a good job
- Examples:
  - One point per square cleaned up in time T ?
  - One point per clean square per time step, minus one per move?
  - Penalize for $> k$ dirty squares?

Rational agent

Definition: For each possible percept sequence, a rational agent should select an action that is expected to maximize its performance measure, given the evidence provided by the percept sequence and whatever built-in knowledge the agent has

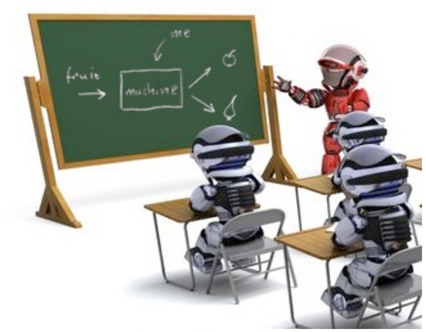
- Rational ≠ omniscient
  - Omniscient agent knows the actual outcome of its actions and can act accordingly
  - percepts may not supply all relevant information
  - action outcomes may not be as expected
- Therefore, rational ≠successful !!!
- Rational is related to exploration, learning, and autonomy

Exploration, learning, autonomy



Exploration: Information gathering in an initially unknown environment

- Maximizing the expected performance
- Doing actions in order to modify future percepts



Learning: Updating information about the environment during perception

- In extreme cases the information is known *a priori*
- In such cases the agent does not need to learn, it just needs to act correctly

Autonomy: Extend to which an agent relies on the prior knowledge of its designer

- Extreme autonomy: relying only its own percepts
- One seldom acquires complete autonomy from the start: it comes with the learning experience

Specifying the task environment

The task environment is defined using PEAS descriptors:

- Performance measure
- Environment
- Actuators
- Sensors

Example: Automated taxi

Performance measures: safety, destination, profits, legality, comfort, *etc*.

Environment: US streets/freeways, traffic, pedestrians, customers, weather, *etc*.

Actuators: steering, accelerator, brake, horn, speakers, display, *etc*.

Sensors: cameras, accelerometers, gauges, engine sensors, keyboard, GPS, *etc*.

Example: Internet shopping agent

Performance measures:

Environment:

Actuators:

Sensors:

Example: Internet shopping agent

Performance measures: price, quality, appropriateness, efficiency

Environment:

Actuators:

Sensors:

Example: Internet shopping agent

Performance measures: price, quality, appropriateness, efficiency

Environment: current and future WWW sites, vendors, shippers

Actuators:

Sensors:

Example: Internet shopping agent

Performance measures: price, quality, appropriateness, efficiency

Environment: current and future WWW sites, vendors, shippers

Actuators: display to user, follow URL, fill in form

Sensors:

Example: Internet shopping agent

Performance measures: price, quality, appropriateness, efficiency

Environment: current and future WWW sites, vendors, shippers

Actuators: display to user, follow URL, fill in form

Sensors: HTML pages (text, graphics, scripts)

Example: Medical diagnosis system

- Agent: Performance measure: Healthy patient, minimize costs, lawsuits
- Environment: Patient, hospital, staff
- Actuators: Screen display (questions, tests, diagnoses, treatments, referrals)
- Sensors: Keyboard (entry of symptoms, findings, patient's answers)

Example: Interactive English tutor

- Performance measure: Maximize student's score on test
- Environment: Set of students
- Actuators: Screen display (exercises, suggestions, corrections)
- Sensors: Keyboard