CMSC 373 Artificial Intelligence Fall 2025 10-RobotsAndAgents

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Review: Meaning Representation Languages

Knowledge Engineering
FOPC
Knowledge Base
Tell-Ask Systems
Forward Chaining Inference
Backward Chaining Inference
Definite Clauses
Logic Programming
PROLOG

Frames
Conceptual Dependency
Semantic Networks

5th Gen. Project, SGI, Alvey, ESPRIT
CYC

Wordnet
Knowledge Graphs

Commonsense Knowledge

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Intelligence Without Representation?

- KR systems are brittle, and expensive (in terms of computational effort)
- KR systems do not scale up (even CYC!)
- "Blocks world is bogus" because it is a toy world and it is simulated (Wooldridge, 2020)
- **Rodney Brooks (1989)**: Systems need to be situated in the real world.

  Intelligent behavior can be generated **without explicit knowledge and reasoning.** Logical reasoning is also expensive. Reasoning is not the starting point of AI.

  Also opposed to divide-and-conquer approach to AI.
- But did Brooks offer an alternative?

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Brooksian Revolution

- Build *artificial creatures*, not artificial humans

  A creature must cope appropriately and in a timely fashion with changes in its dynamic environment.

  A Creature should be robust (i.e. not brittle) in response to changes in its environment.

  A creature should be able to maintain multiple goals and have the ability to switch based on the circumstances.

  A creature should do *something* in the world; it should have a purpose for its being.

From: https://people.csail.mit.edu/brooks/all%20images/company%20images/brooks_sept_2021.jpg

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Behavioral AI

- **Subsumption Architecture**

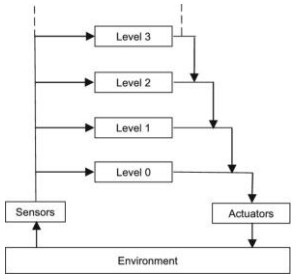
  Situatedness
  Embodiment
  Intelligence bottom up
  Emergence

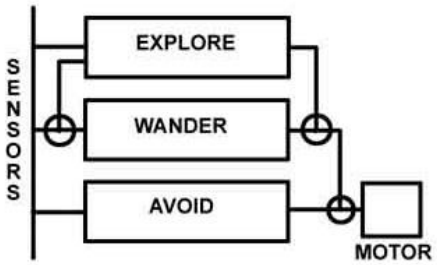
- Layers of control

  All layers may have an action to suggest.
  Only one will be carried out at any time.
  The action from the "lowest" (highest) module.
  E.g. AVOID subsumes WANDER.
  WANDER subsumes EXPLORE.

- Built several robots: Allen, Herbert, Tom & Jerry, Seymour, **Genghis**, Squirt.

Genghis Link: https://www.youtube.com/watch?v=1j6CliOwRng





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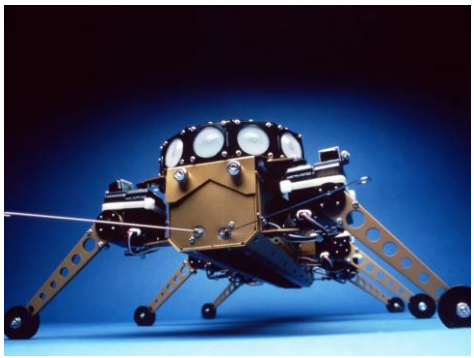
Genghis Video

- ABC News Nightline, *Robots Like Us*, 1996. [on dvd]



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Cog - A Humanoid Robot (1993-2003)

- Motivation: *Humanoid intelligence requires humanoid interactions with the world.*
- It turns out to be easier to build real robots than to simulate complex interactions with the world, including perception and motor control. Leaving those things out would deprive us of key insights into the nature of human intelligence.

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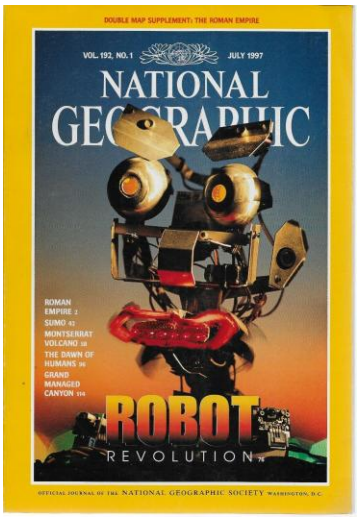
Robotics Becomes Mainstream



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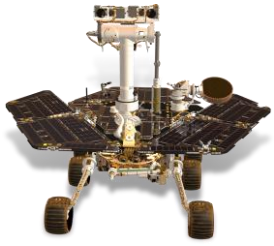
Some famous robots (NASA)

Mars Pathfinder 1997



Spirit & Opportunity
2004-2010, 2004-2018

Mars Curiosity Rover
Launched 11/2011, landed 8/2012

Ingenuity Helicopter
Launched 7/2020, landed 2/2021

From: https://mars.nasa.gov/mer/

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Boston Dynamics Big Dog (2010)

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Boston Dynamics – Spot (2019)

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Boston Dynamics – Atlas (2025)

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Agent-Based AI (1990s)

- Mostly disembodied AI agents
- A complete autonomous software entity (software agents)
  Partly fueled by the development of the World Wide Web

  shopping agents, e-mail assistants, etc.
- 2010 Apple launched Siri
- Others followed: Alexa, Google's Assistant, Microsoft's Cortana

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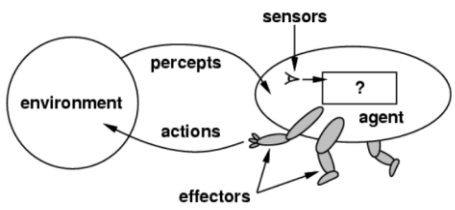
Intelligent Agents (or Agentic AI)

- An intelligent agent perceives its environment via **sensors** and acts rationally in that environment with its **effectors**.

  Properties:

  - Autonomous
  - Reactive
  - Pro-active (goal-directed)
  - Interacts with other agents.



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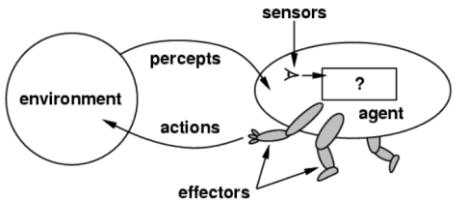
Agent Types



- **Table-Driven Agents**
  Use a **percept-action table** in to find next action.
- **Simple Reflex Agents**
  Based on **condition-action rules**
- **Agents with Memory**
  Have **internal states** that are used to keep track of past states of the world.
- **Agents with Goals**
  Have state and goal information to take future states into consideration.
- **Utility-Based Agents**
  Use **utility theory** to act rationally.
- **LLM-Based Agents**
  Carry out actions recommended by an LLM.

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Other Successful Approaches

- Rational Agents (Utility based agents)
- Bayesian Inference
- 1997: IBM's Deep Blue beat Garry Kasparov
- 2012: IBM's Watson wins Jeopardy!

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IBM's Watson Jeopardy! (2011)

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The Seasons of AI

- **1950s – 1966 First AI Summer: Irrational Exuberance**

  Early successes in game playing, theorem proving, problem solving

- **1967 – 1977 First AI Winter**

  No useful deliverables led to loss of research funding and cancellation of AI programs. In UK *The Lighthill Report* (toy AI systems do not scale due to combinatorial explosion).

- **1978 – 1987 Second AI Summer/Spring**

  Rise of knowledge-based systems, success of Expert Systems. Boom times.

- **1988 – 1993 Second AI Winter**

  Failure of AI Hardware companies (Symbolics, LMI, Lisp Machines) and AI Companies (Teknowledge, Inference Corp. etc.) Commercial deployments of Expert Systems were discontinued.

- **1993 – 2011 Third AI Summer (Mostly academic advances)**

  Statistical approaches and extensions to logic (Bayesian Nets), Non-Monotonic Reasoning (in Logic), Fuzzy Logic, advances in Machine Learning (Decision Trees, Random Forests, Neural Nets), Cognitive Models, Logic Programming, Case-Based Reasoning, Genetic Algorithms, Agent-based approaches, etc.

- **2011 – Now Third AI Spring/Summer/Hype?**

  Rise of Deep Learning, Neuro-symbolic AI, ChatGPT and other chatbots, generative AI.

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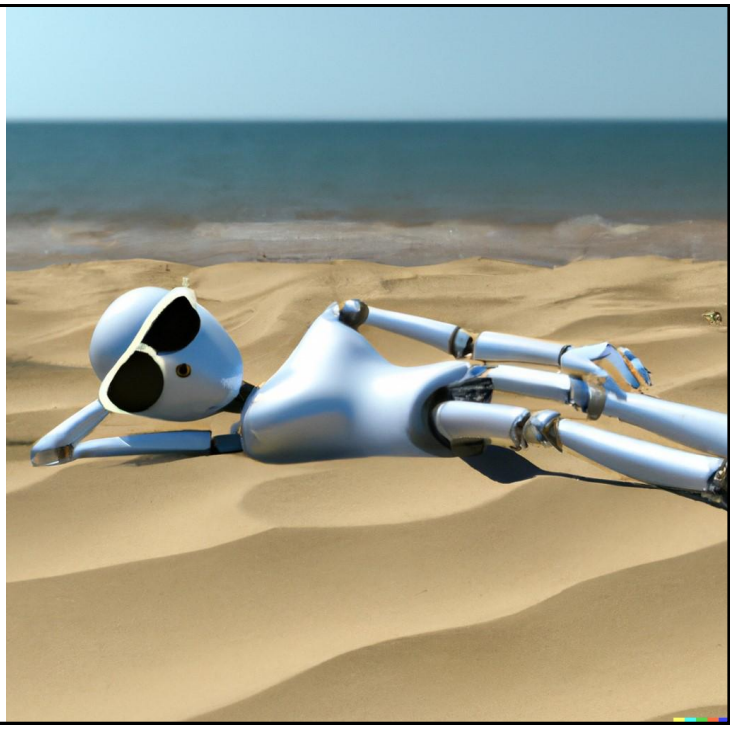
AI Summer/Spring? 1993-2011



Picture made by Dall-E: https://labs.openai.com/ October 6, 2023.

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Vocabulary

Intelligence w/o Representation
Behavioral AI
Subsumption Architectures
Genghis, Cog
NASA Pathfinder
NASA Spirit & Opportunity
NASA Curiosity, Ingenuity
Boston Dynamics Big Dog
Boston Dynamics Spot, Atlas
Agent-Based AI
Types of Agents
Agentic AI
IBM Watson

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References

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