MC/MS 4112
Artificial Intelligence

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- Required Reading
  - Peter Norvig and Stuart J. Russell - “Artificial Intelligence: A Modern Approach”

- Grading:
  - Quizzes (MCQ)
  - Midterm
  - Endterm

Goals of this Course

- To introduce you to a set of keys:
  - Paradigms &
  - Techniques
- Teach you to identify when and how to use
  - Heuristic search
  - Constraint satisfaction
  - Machine learning
  - Logical inference
  - Bayesian inference
  - Policy construction
- Highlight directions for AI-based Projects

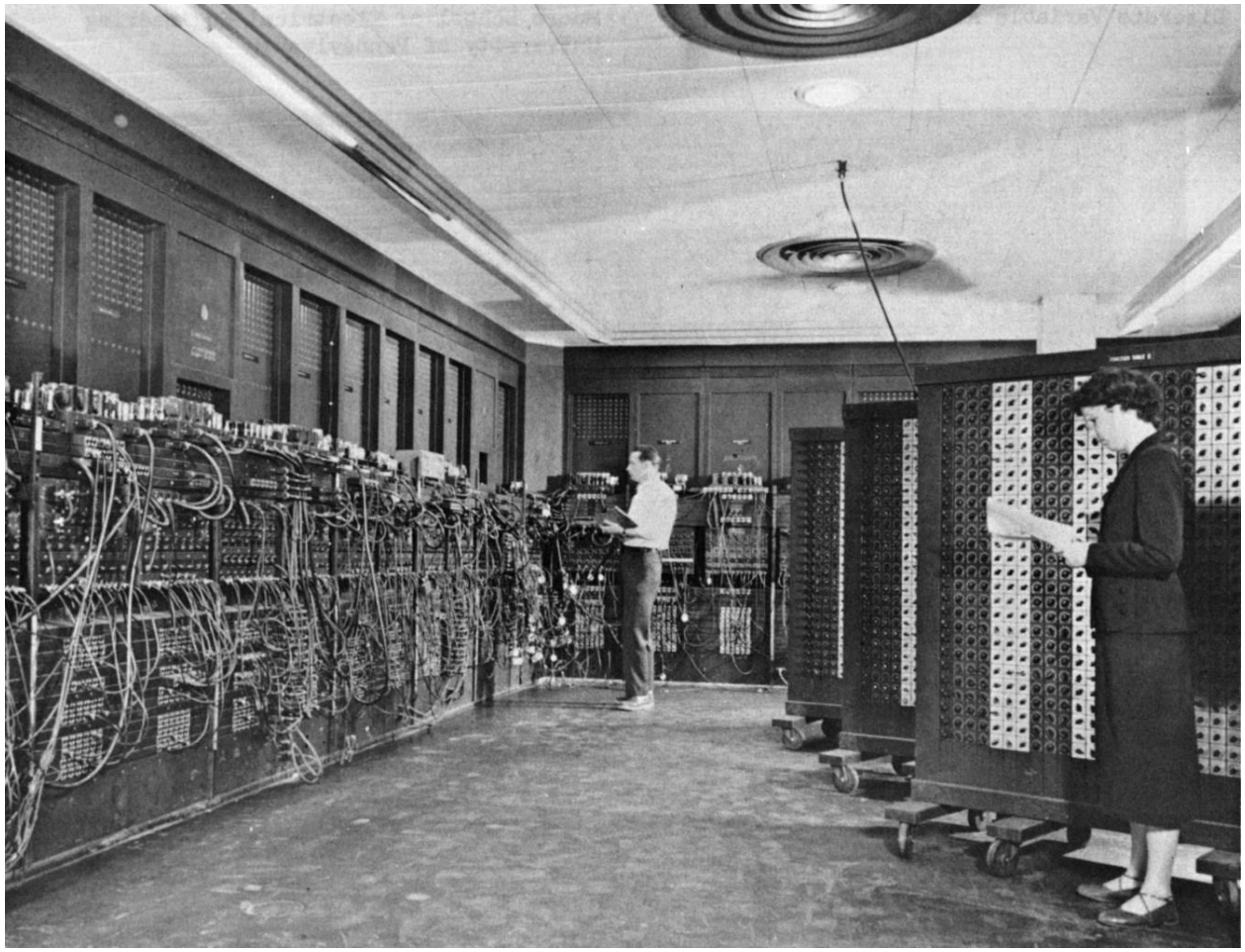
Outline

- History and Present
- What is AI?
- State of the Art
- Challenges

Historical Perspective

- (4th C BC+) Aristotle, George Boole, Gottlob Frege, Alfred Tarski
    - formalizing the laws of human thought
- (16th C+) Gerolamo Cardano, Pierre Femat, James Bernoulli, Thomas Bayes
    - formalizing probabilistic reasoning
- (1950+) Alan Turing, John von Neumann, Claude Shannon
    - thinking as computation
- (1956) John McCarthy, Marvin Minsky, Herbert Simon, Allen Newell
    - Start of the field of AI

1946: ENIAC heralds the dawn of Computing



1950: Turing asks the question….

I propose to consider the question:

“Can machines think?”

--Alan Turing, 1950

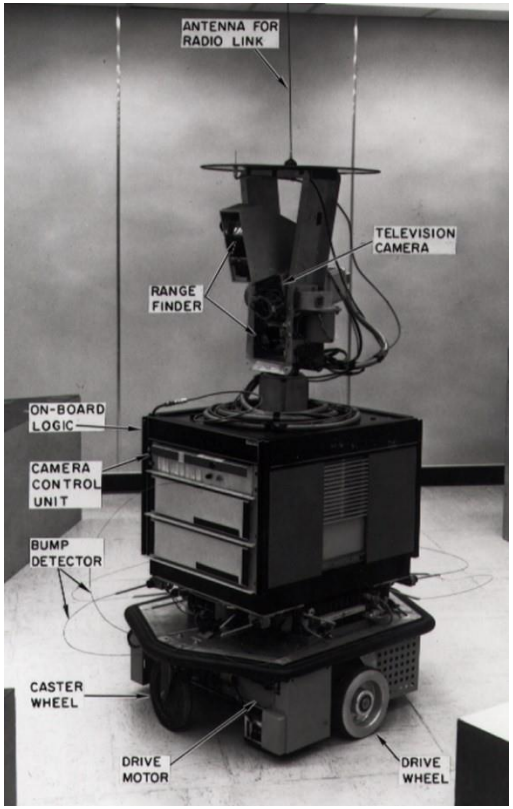
1956: A new field is born

- We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire.

– Dartmouth AI Project Proposal; J. McCarthy et al.; Aug. 31, 1955.

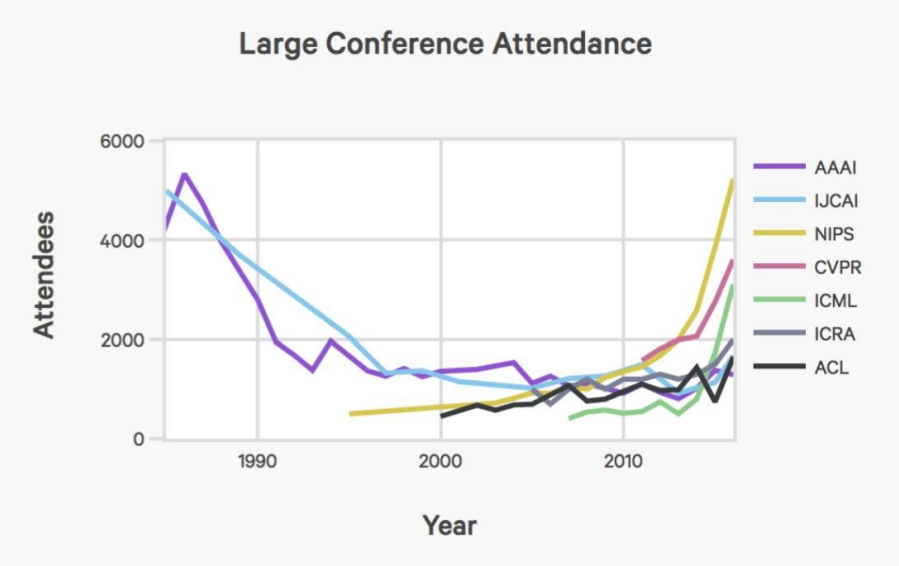
1956-1966

- 1950: Turing Test for Machine Intelligence
- 1956: AI born at Dartmouth College Wrkshop
- 1964: Eliza – the chatbot psychotherapist
- 1966: Shakey – general purpose mobile robot



AI Winters

- 1974 – 1980: Winter #1
  - Failure of machine translation
  - Negative results in Neural nets
  - Poor speech understanding
- 1987 – 1993: Winter #2
  - Decline of LISP
  - Decline of specialized hardware for expert systems



- Lasting effects
  - [Economist07] “Artificial Intelligence is associated with systems that have all too often failed to live up to their promises.”
  - [Pittsburgh BT06] “Some believe the word 'robotics' actually carries a stigma that hurts a company's chances at funding.”

1996: EQP proves that Robbin's Algebras are all boolean

```
----- EQP 0.9, June 1996 -----
The job began on eyas09.mcs.anl.gov, Wed Oct 2 12:25:37 1996
UNIT CONFLICT from 17666 and 2 at 678232.20 seconds.
_____PROOF _____
2 (wt=7) [] -(n(x + y) = n(x)).
3 (wt=13) [] n(n(n(x) + y) + n(x + y)) = y.
5 (wt=18) [para(3,3)] n(n(n(x + y) + n(x) + y) + y) = n(x + y).
6 (wt=19) [para(3,3)] n(n(n(n(x) + y) + x + y) + y) = n(n(x) + y).
…….
17666 (wt=33) [para(24,16426),demod([17547])] n(n(n(x) + x) ….
```

[An Argonne lab program] has come up with a major mathematical proof that would have been called creative if a human had thought of it.
-New York Times, December, 1996

1997: Deep Blue ends Human Supremacy in Chess

Deep Blue had Kasparov in deep thought (CNN)

vs.

The cunning Deep Blue (CNN)

I could feel human-level intelligence across the room

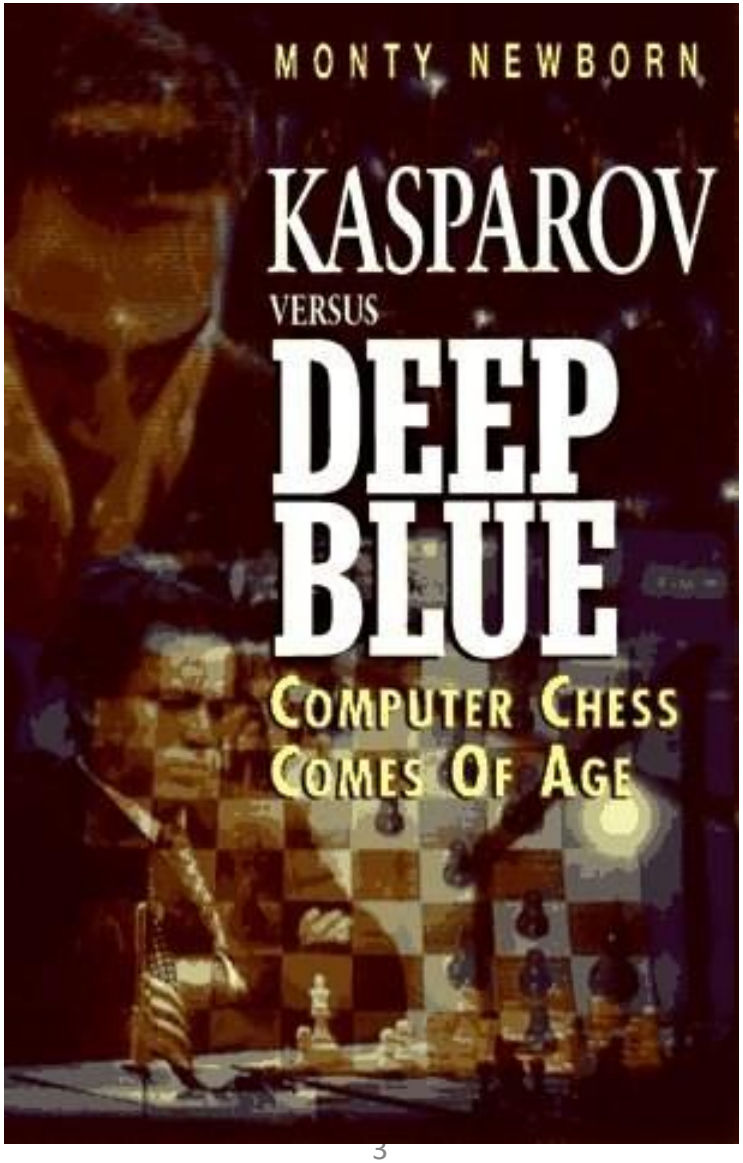
-Gary Kasparov, World Chess Champion (human)

In a few years, even a single victory in a long series of games would be the triumph of human genius.

Success Story: Chess

Does Deep Blue use AI?

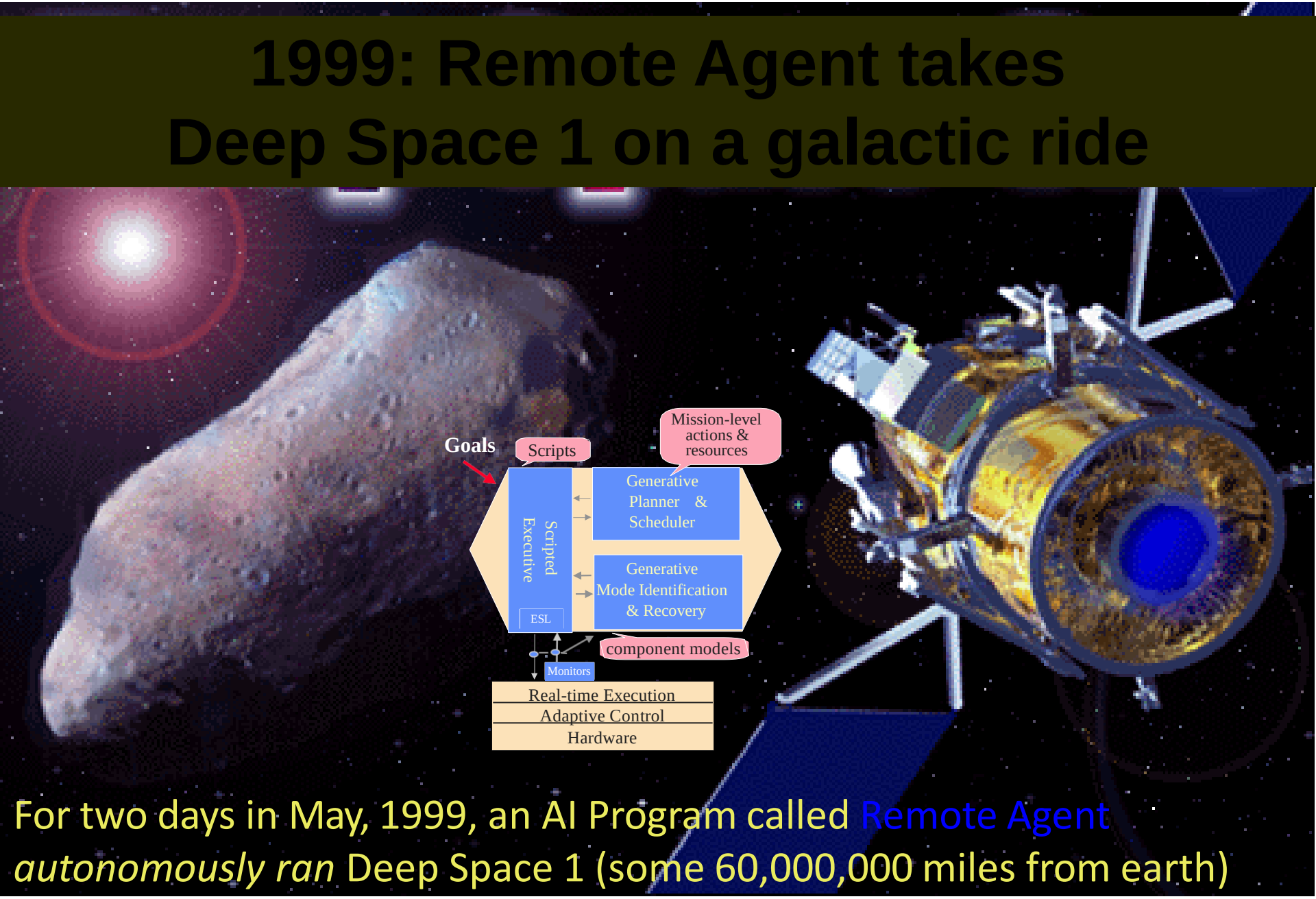
"If it works, its not AI!"



Saying Deep Blue doesn't really think about chess is like saying an airplane doesn't really fly because it doesn't flap its wings.

– Drew McDermott

1999: Remote Agent takes Deep Space 1 on a galactic ride



For two days in May, 1999, an AI Program called Remote Agent *autonomously ran* Deep Space 1 (some 60,000,000 miles from earth)

2004 & 2009

2005: Cars Drive Themselves

- Stanley and three other cars drive themselves over a 132 mile mountain road

DARPA GRAND CHALLENGE

2005: Cars Drive Themselves

- Stanley and three other cars drive themselves over a 132 mile mountain road

2011: IBM's Watson

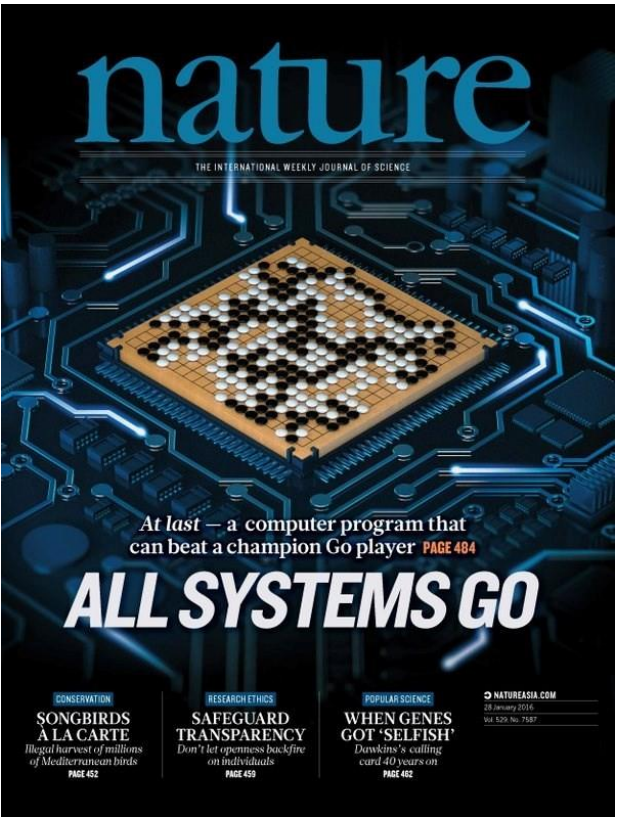
And Ken Jennings pledges obeisance to the new Computer Overlords..

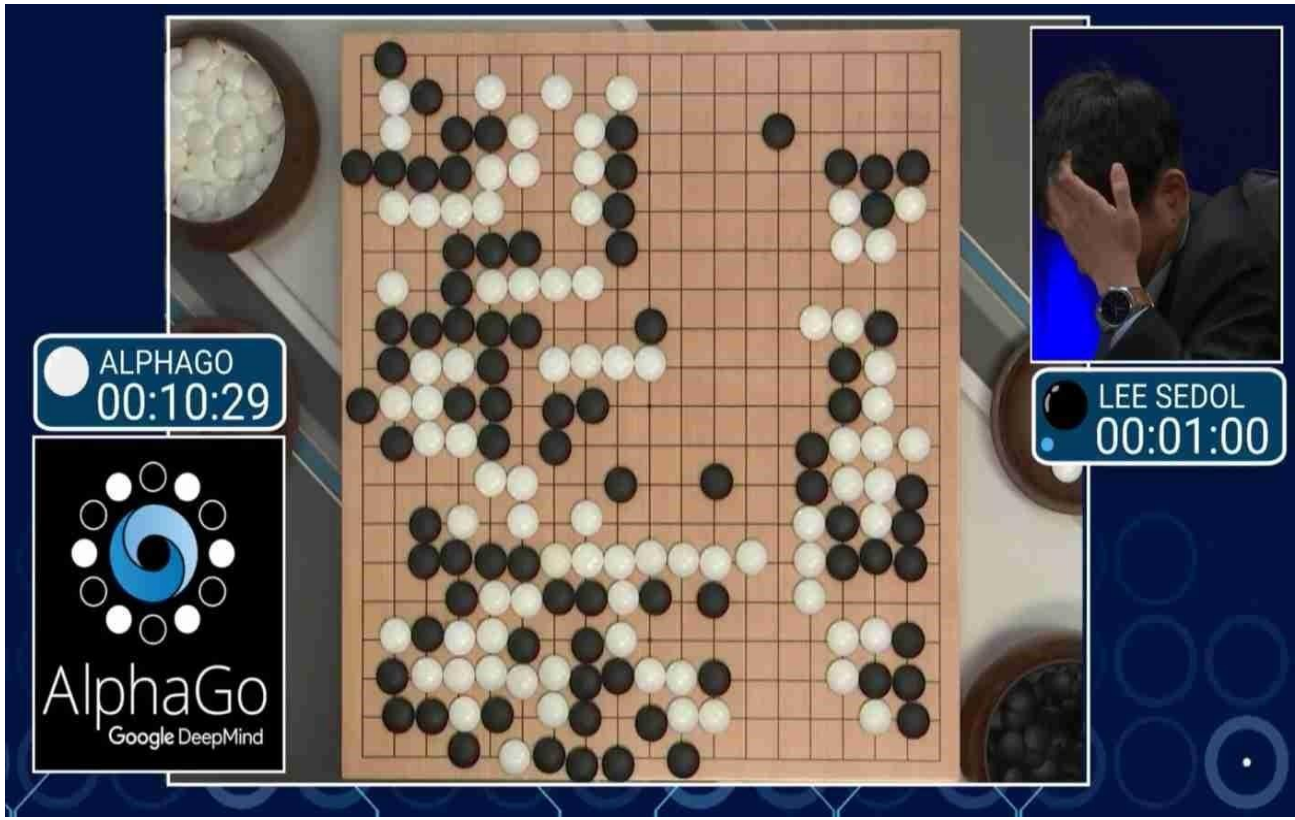
2011: IBM's Watson

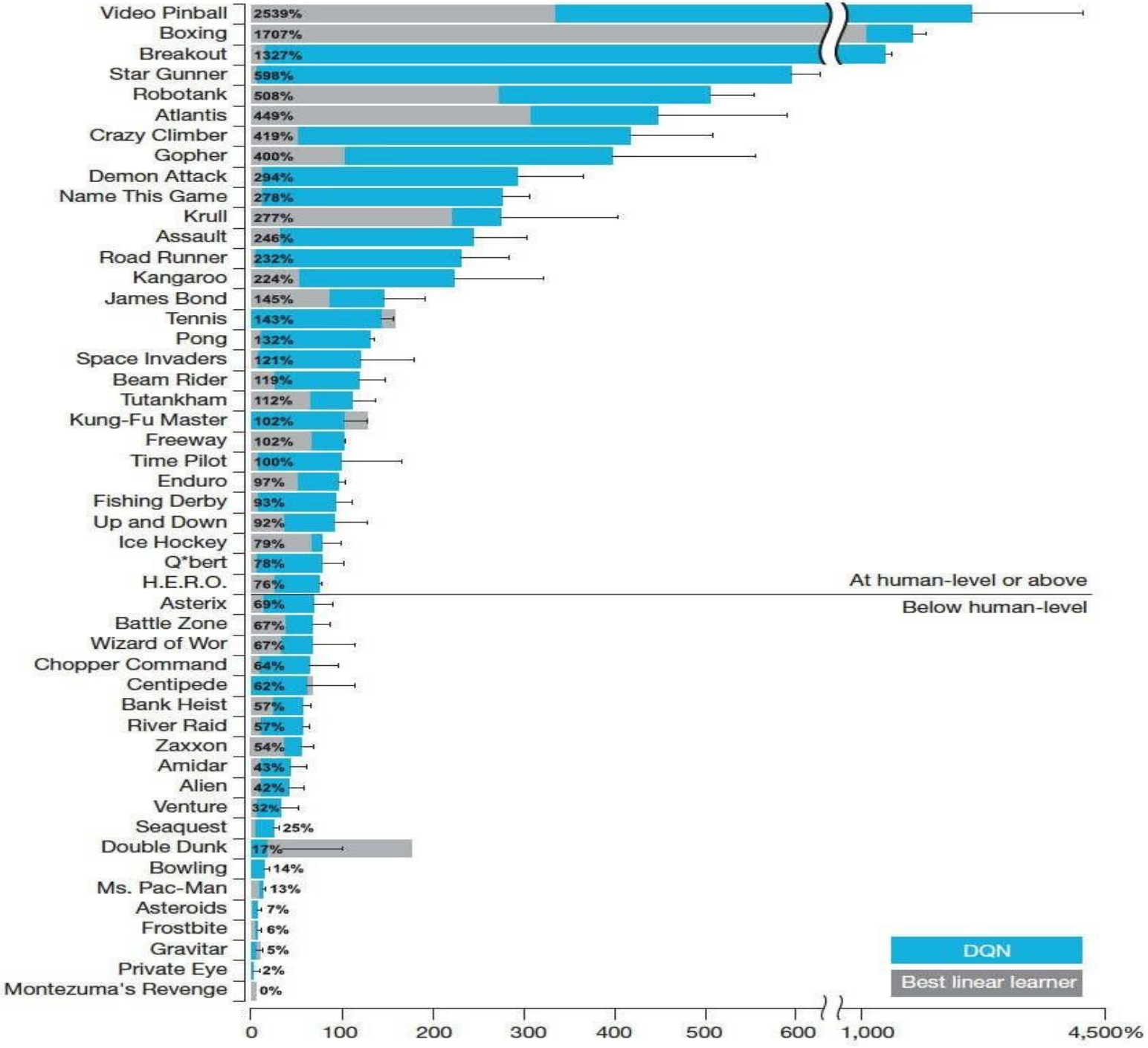
https://www.youtube.com/watch?v=WFR3lOm_xhE

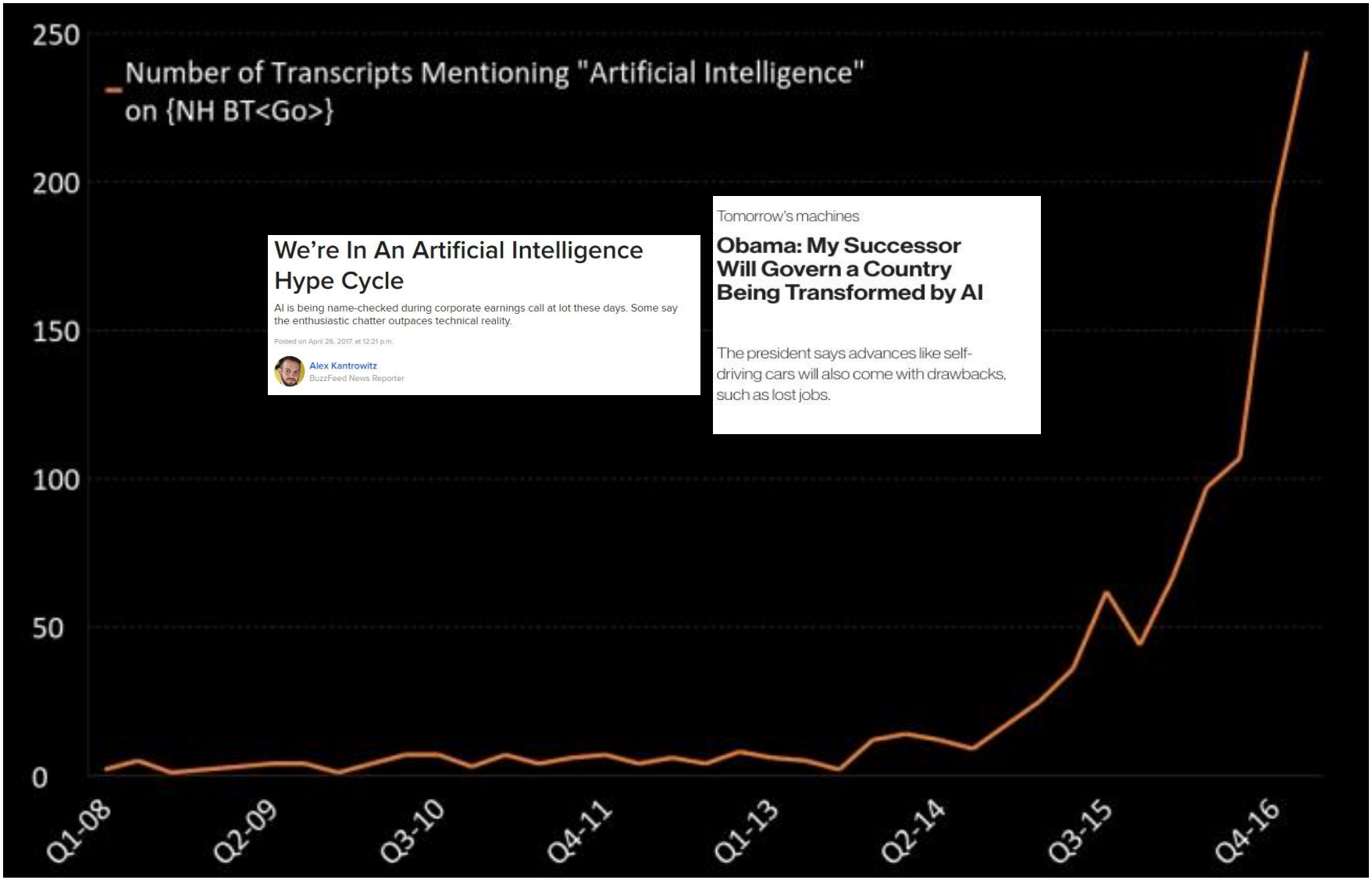
PRESENT

2016: AlphaGo



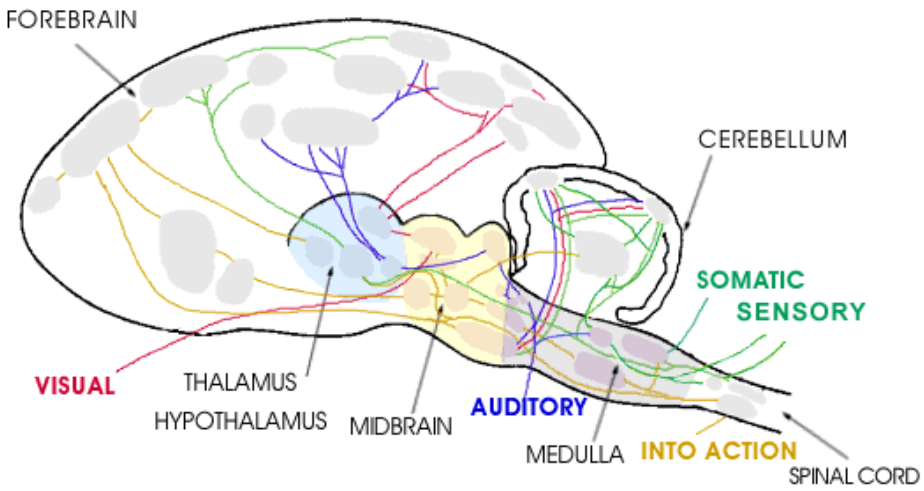



Video Pinball 2539%
Boxing 1707%
Breakout 1327%
Star Gunner 598%
Robotank 508%
Atlantis 449%
Crazy Climber 419%
Gopher 400%
Demon Attack 294%
Name This Game 278%
Krull 277%
Assault 246%
Road Runner 232%
Kangaroo 224%
James Bond 145%
Tennis 143%
Pong 132%
Space Invaders 121%
Beam Rider 119%
Tutankham 112%
Kung-Fu Master 102%
Freeway 102%
Time Pilot 100%
Enduro 97%
Fishing Derby 93%
Up and Down 92%
Ice Hockey 79%
Q*bert 78%
H.E.R.O. 76%
Asterix 69%
Battle Zone 67%
Wizard of Wor 67%
Chopper Command 64%
Centipede 62%
Bank Heist 57%
River Raid 57%
Zaxxon 54%
Amidar 43%
Alien 42%
Venture 32%
Seaquest 25%
Double Dunk 17%
Bowling 14%
Ms. Pac-Man 13%
Asteroids 7%
Frostbite 6%
Gravitar 5%
Private Eye 2%
Montezuma's Revenge 0%
At human-level or above
Below human-level
DQN
Best linear learner
0
100
200
300
400
500
600
1,000
4,500%



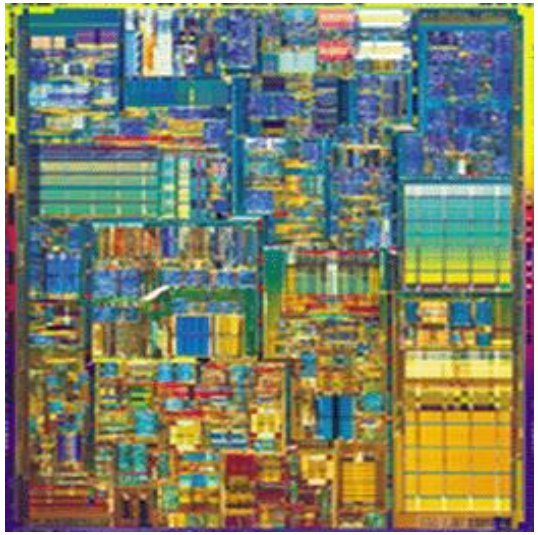
© https://www.buzzfeednews.com/article/alexkantrowitz/were-in-an-artificial-intelligence-hype-cycle

Brain V/s Hardware



10^{11} neurons
10^{14} synapses
cycle time: 10^{-3} sec

10^{7} transistors
10^{10} bits of RAM
cycle time: 10^{-9} sec



Computer vs. Brain

HUMAN BRAIN -v- COMPUTER

	BRAIN 	COMPUTER
Size and Weight	Volume 1500 cm^3 , Weight 3.3 lbs.	Variable Weight and Size.
Construction	Neurons and Synapses	Chips, Circuits, Artificial Neurons
Structure	Bio-Genetic Programmed, Self-Learning	Pre-Programmed, AI+ML Learning to Learn
Memory	Increases by Connecting Synapses	Increased by Adding More/Better Chips
Memory Power	Teraflops (100 Trln calculations/sec)	Megabytes, Terabytes, and Zettabytes
Memory Density	10^7 circuits/cm^3	10^{14} Bits/cm^3 , and now Qubits
Info Storage	In Electrochemical and Electric Impulses	In Numeric / Symbolic Form (Binary Bits)
Info Transmission	Chemicals Fire Action Potential in Neurons	Communicates via Electrical Coded Signals
Input Tools	Human Sensory Organs	Keyboard, Mouse, Camera, Touch, Vision
Energy use	12 watts of Power; 5-10 Joules/sec	Gigawatts of Power; 10-16 Joules/sec

Sources: Various; Diagram by Frank Feather (Note: Computers are constantly advancing)

What is Intelligence?

- Dictionary.com: *capacity for learning, reasoning, understanding, and similar forms of mental activity*

- Ability to perceive and act in the world
- Reasoning: proving theorems, medical diagnosis
- Planning: take decisions
- Learning and Adaptation: recommend movies, learn traffic patterns
- Understanding: text, speech, visual scene

Dimensions of the AI Definition

thought *vs.* behavior \ human-like *vs.* rational		
	Systems that think like humans	Systems that think rationally
	Systems that act like humans	Systems that act rationally

Thinking Humanly

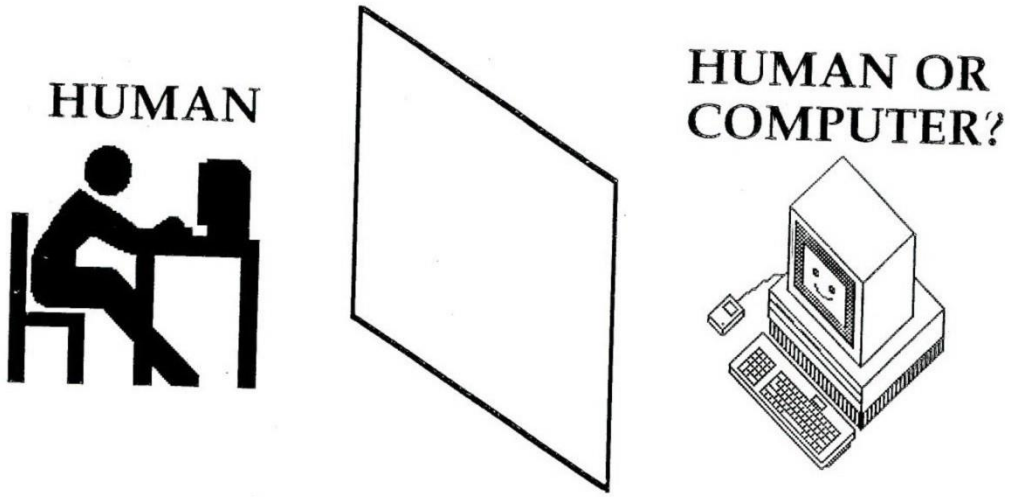
- Cognitive Science
  - Very hard to understand how humans think
    - Post-facto rationalizations, irrationality of human thinking
- Do we want a machine that beats humans in chess or a machine that *thinks like humans* while beating humans in chess?
  - Deep Blue supposedly DOESN'T think like humans..
- Thinking like humans important in Cognitive Science applications
  - Intelligent tutoring
  - Expressing emotions in interfaces… HCI
- The goal of aeronautical engg is not to fool pigeons in flying!

Thinking Rationally: laws of thought

- Aristotle: what are correct arguments/thought processes?
  - Logic
- Problems
  - Not all intelligent behavior is mediated by logical deliberation (reflexes)
  - What is the purpose of thinking?

Acting Humanly: Turing's Test

- If the human cannot tell whether the responses from the other side of a wall are coming from a human or computer, then the computer is intelligent.



Acting Humanly

- Loebner Prize
  - Every year in Boston
  - Expertise-dependent tests: limited conversation
- What if people call a human a machine?
  - Shakespeare expert
  - Make human-like errors
- Problems
  - Not reproducible, constructive or mathematically analyzable

Acting rationally

- Rational behavior: doing the right thing
- Need not always be deliberative
  - Reflexive
- Aristotle (Nicomachean ethics)
  - Every art and every inquiry, and similarly every action and every pursuit is thought to aim at some good.

Acting → Thinking?

- Weak AI Hypothesis vs. Strong AI hypothesis
  - Weak Hyp: machines could act as if they are intelligent
  - Strong Hyp: machines that act intelligent have to think intelligently too

Rational Agents

- An agent should strive to do the right thing, based on what it can perceive and the actions it can perform. The right action is the one that will cause the agent to be most successful

- Performance measure: An objective criterion for success of an agent's behavior

- E.g., performance measure of a vacuum-cleaner agent could be amount of dirt cleaned up, amount of time taken, amount of electricity consumed, amount of noise generated, etc.

Ideal Rational Agent

"For each possible percept sequence, does whatever action is expected to maximize its performance measure on the basis of evidence perceived so far and built-in knowledge."

- Rationality vs omniscience?
- Acting in order to obtain valuable information

What is *artificial* intelligence (agent view)

- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators

- Human agent:
  - eyes, ears, and other organs for sensors
  - hands, legs, mouth, and other body parts for actuators

- Robotic agent:
  - cameras and laser range finders for sensors
  - various motors for actuators

- We will revisit this view in detail later in the course

Examples: Formal Cognitive Tasks

- Games
  - Chess
  - Checkers
  - Othello
- Mathematics
  - Logic
  - Geometry
  - Calculus
  - Proving properties of programs

Examples: Expert Tasks

- Engineering
  - Design
  - Fault Finding
  - Manufacturing planning
- Medical
  - Diagnosis
  - Medical Image Analysis
- Financial
  - Stock market predictions

Examples: Perceptual Tasks

- Perception
  - Vision
  - Speech
- Natural Language
  - Understanding
  - Generation
  - Translation
- Robot Control

What is *artificial* intelligence (algorithmic view)

- A large number of problems are NP hard

- AI develops a set of tools, heuristics, …
  - to solve such problems in practice
  - for naturally occurring instances

- Search
- Game Playing
- Planning
- …

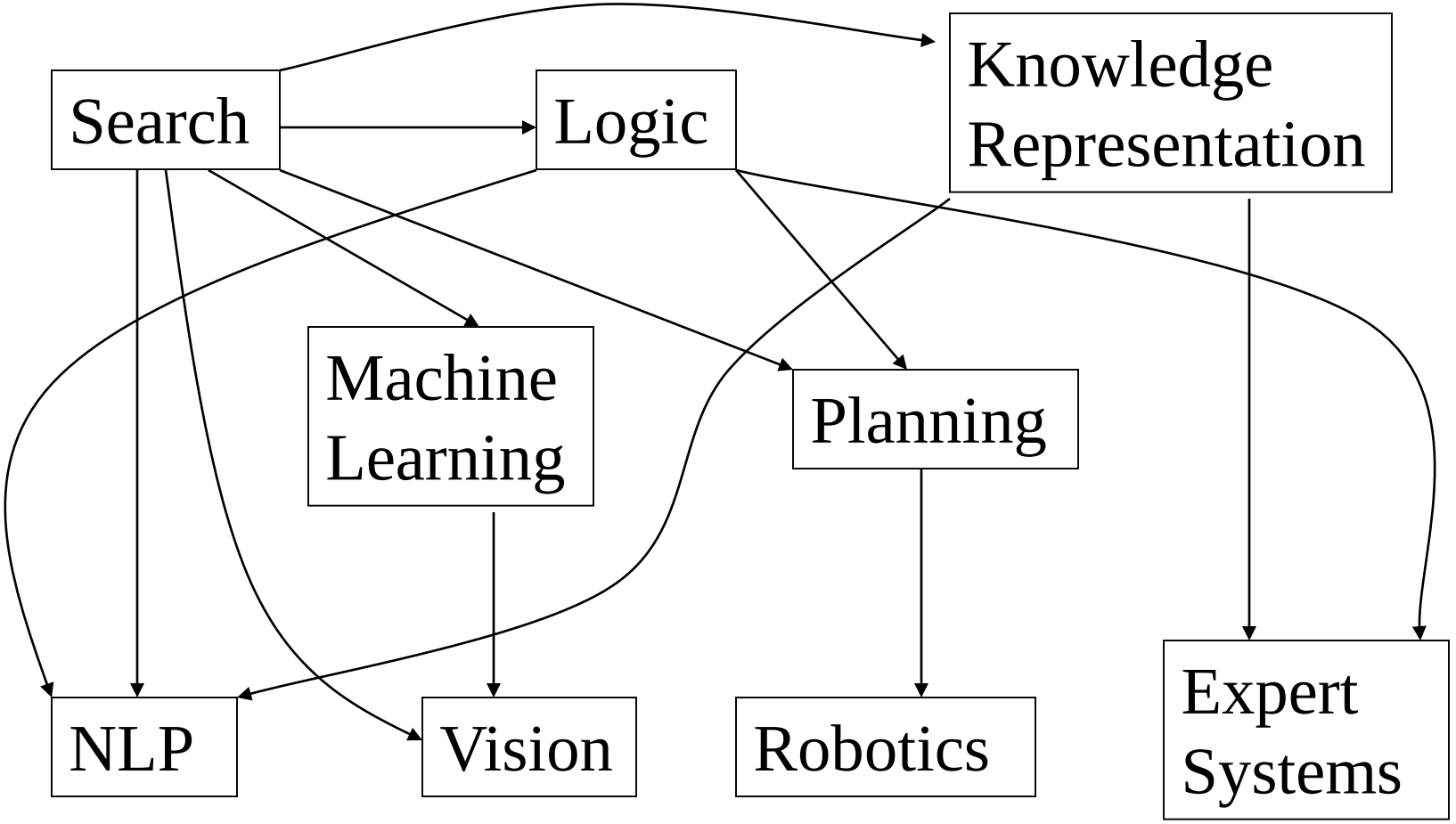
Recurrent Themes

- Weak *vs.* Knowledge-based Methods
  - Weak – general search methods (e.g., A* search)
    - primarily for problem solving
    - not motivated by achieving human-level performance
  - Strong AI -- knowledge intensive (e.g., expert systems)
    - more knowledge $\Rightarrow$ less computation
    - achieve better performance in specific tasks
  - How to combine weak & strong methods seamlessly?

Recurrent Themes

- Logic *vs.* Probabilistic vs. Neural
  - In 1950s, logic dominates
    - attempts to extend logic
  - 1988 – Bayesian networks
    - efficient computational framework
  - 2013 – deep neural networks
    - powerful representation across modalities

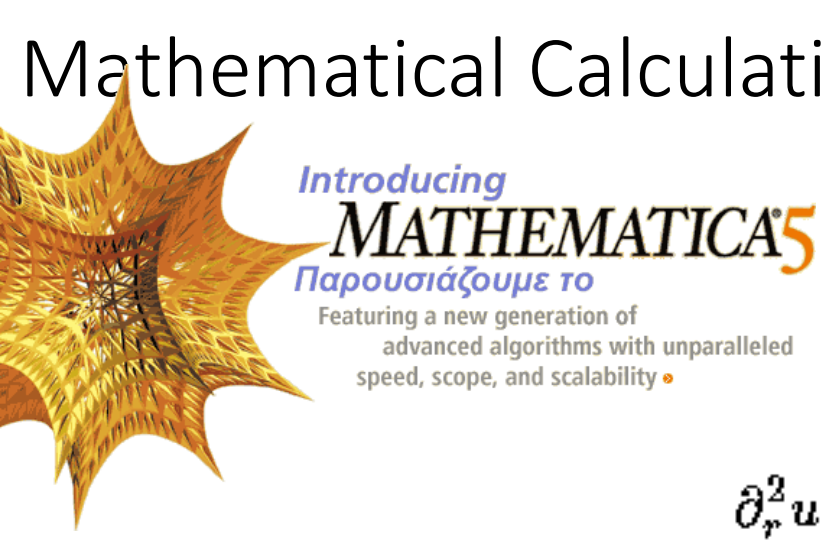
Areas of AI and Some Dependencies



AI as Engineering

- How can we make software systems more powerful and easier to use?
  - Speech & intelligent user interfaces
  - Autonomic computing
  - SPAM detection
  - Mobile robots, softbots & immobots
  - Data mining
  - Modeling biological systems
  - Medical expert systems...

Mathematical Calculation



$$\partial_r^2 u = -\left[E' - \frac{l(l+1)}{r^2} - r^2\right] u(r)$$

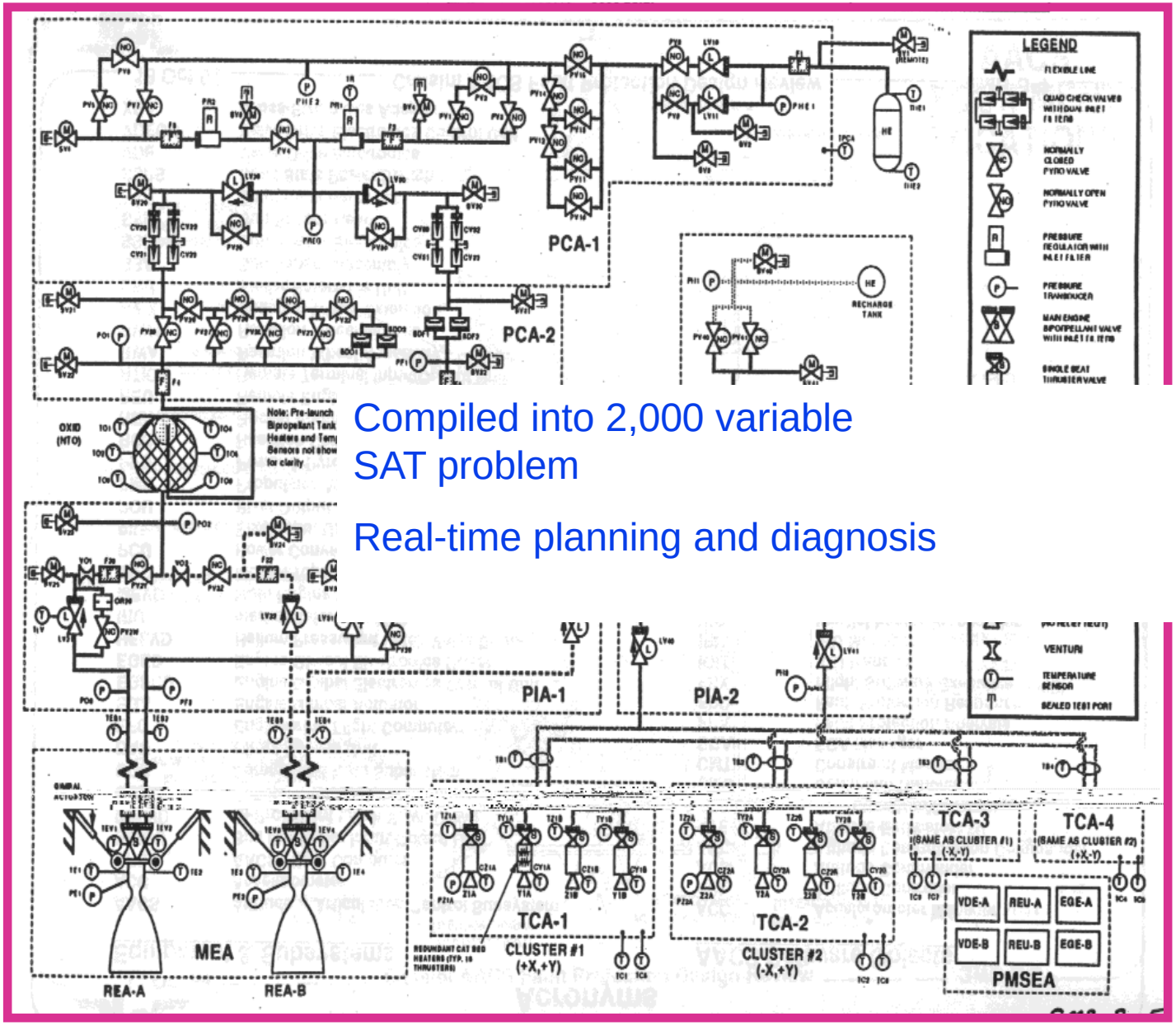
$$e^{-2s}\left(\partial_s^2 - \partial_s\right) u(s) = -\left[E' - l(l+1)e^{-2s} - e^{2s}\right] u(s)$$

$$e^{-2s}\left[e^{\frac{1}{2}s}\left(e^{-\frac{1}{2}s}u(s)\right)'' - \frac{1}{4}u\right] = -\left[E' - l(l+1)e^{-2s} - e^{2s}\right] u(s)$$

$$e^{-2s}\left[e^{\frac{1}{2}s}\left(e^{-\frac{1}{2}s}u(s)\right)''\right] = -\left[E' - \left(l+\frac{1}{2}\right)^2 e^{-2s} - e^{2s}\right] u(s)$$

$$v'' = -e^{2s}\left[E' - \left(l+\frac{1}{2}\right)^2 e^{-2s} - e^{2s}\right] v$$

Shuttle Repair Scheduling

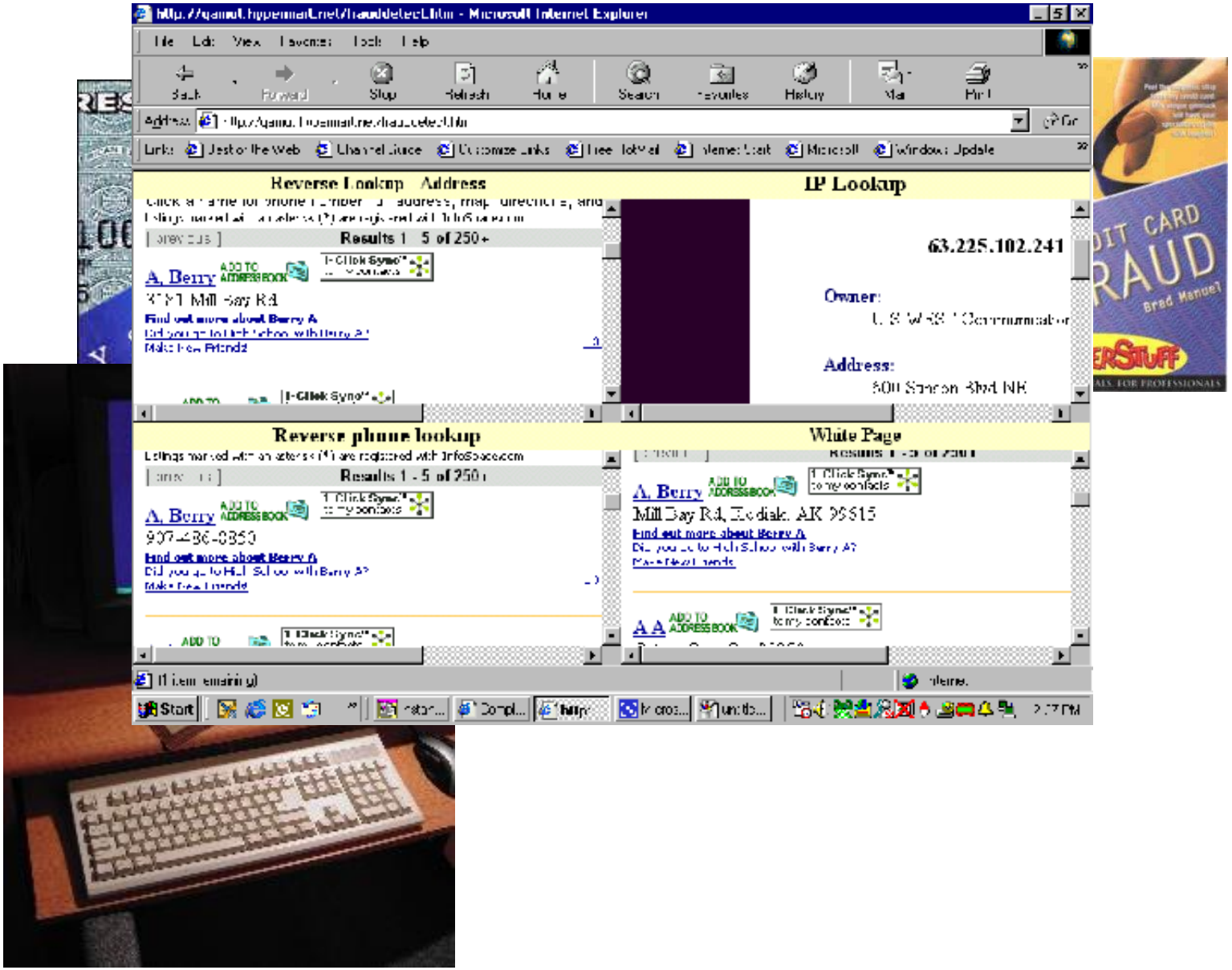


Compiled into 2,000 variable SAT problem

Real-time planning and diagnosis

Europa Mission ~ 2018

Credit Card Fraud Detection



Speech Recognition

Autonomous Navigation: NAVLAB 1

NAVLAB 2

NAVLAB 11

Limits of AI Today

- Today's successful AI systems
  - operate in well-defined domains
  - employ narrow, specialize knowledge

- *Commonsense Knowledge*
  - needed in complex, open-ended worlds
    - Your kitchen vs. GM factory floor
  - understand unconstrained Natural Language