
AI

Artificial Intelligence

8.1.1 Introduction

CPSC 470/570 Artificial Intelligence

- Instructor:
  - Dragomir Radev
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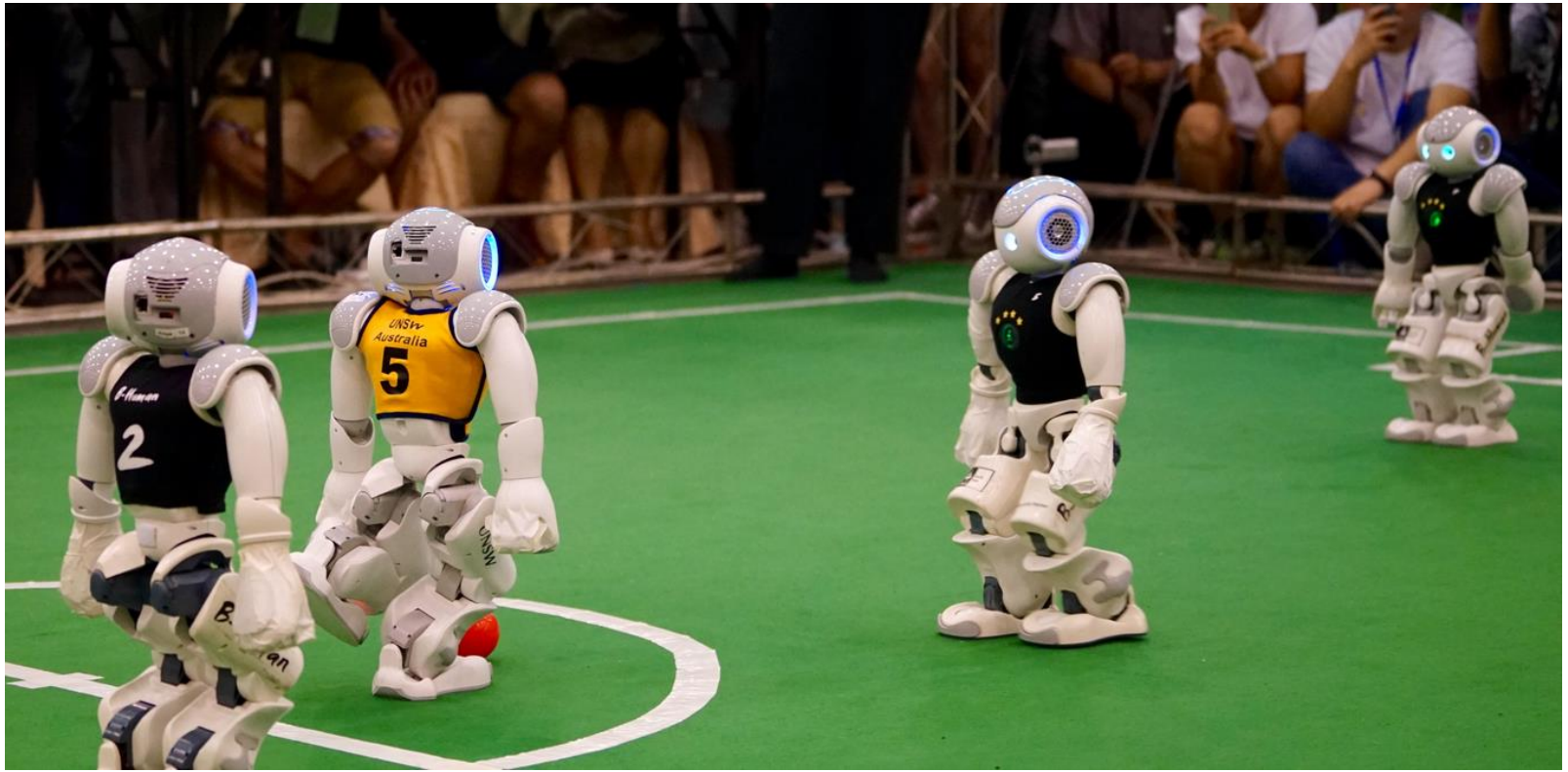
- Class times:
  - TTh 4-5:15
  - Davies Auditorium, 15 Prospect
- TF
  - Meiying Qin
- ULA
  - Soumya Kambhampati
  - Andrew Malta
  - William Merrill

http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/siri.htm

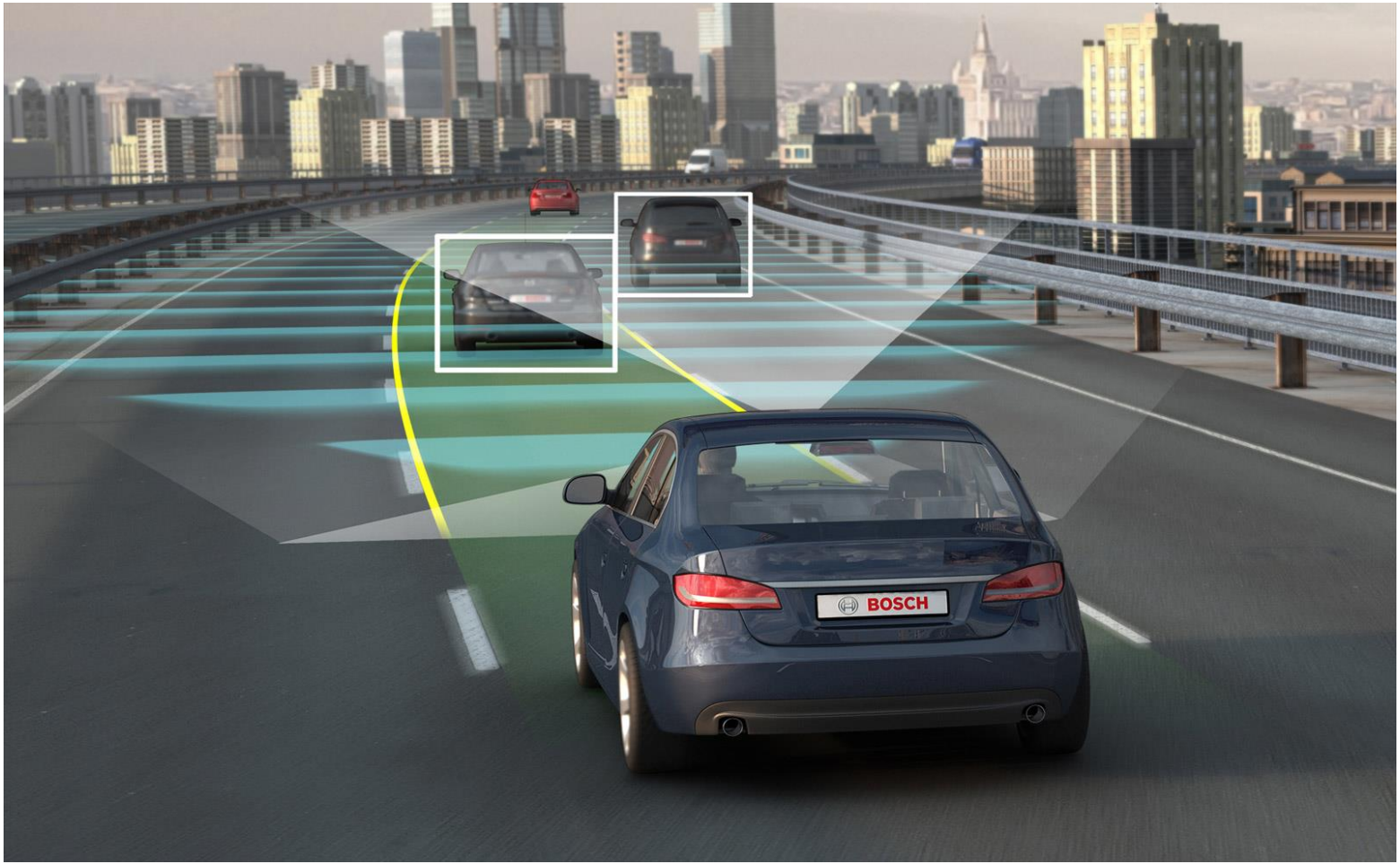
http://www.tomshardware.com/news/alphago-narrow-win-ke-jie,34486.html

http://www.geekwire.com/2013/ibm-takes-watson-cloud/



Sean Harris

https://theconversation.com/how-we-won-the-world-robot-soccer-championship-45156



https://infograph.venngage.com/p/97547/autonomous-cars-infographic-group-work

Lecture Outline

- Course overview
- Logistics
- What is AI?
- A brief history
- The state of the art
- Programming languages

Major Goals of the Class

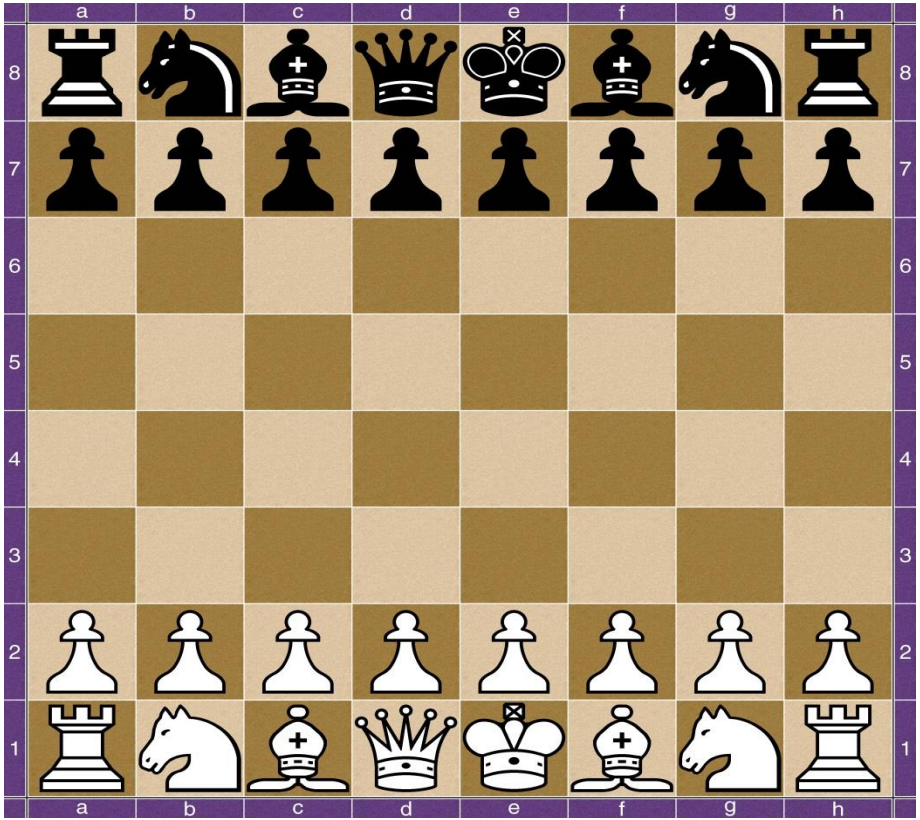
- Learn the basic principles and theoretical issues underlying artificial intelligence
- Understand why artificial intelligence is difficult
- Learn techniques and tools used to build practical, realistic, robust AI systems
- Understand the limitations of these techniques and tools
- Gain insight into some open research problems in AI

Practically…

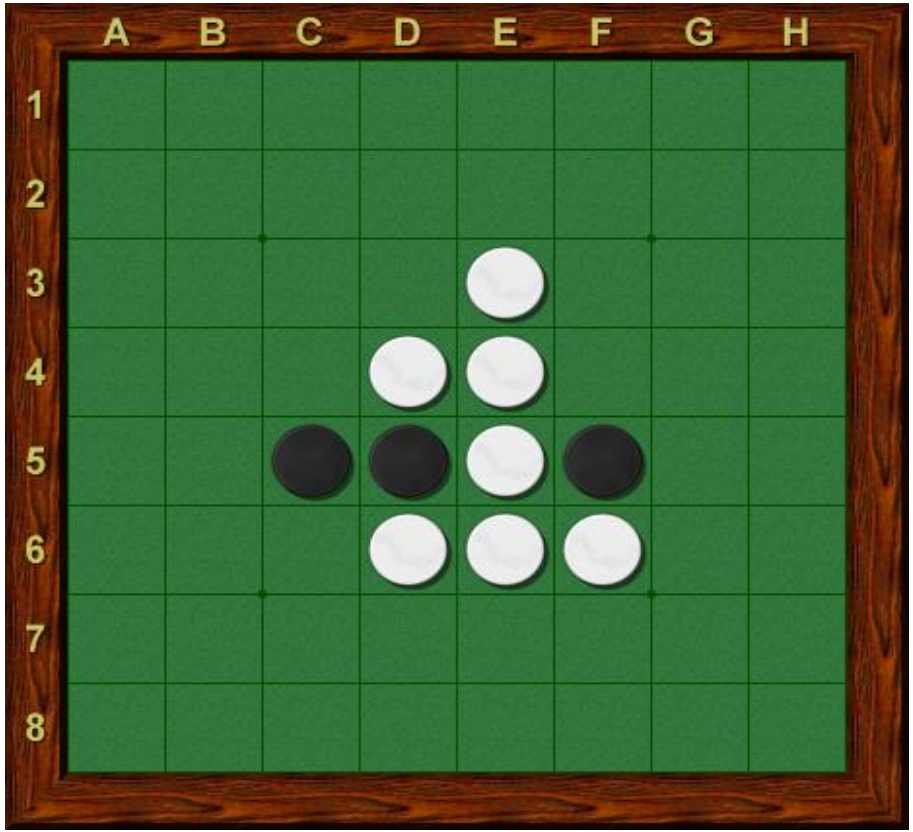
- Playing games
- Language
- Learning
- Interacting with the environment

15 Puzzle

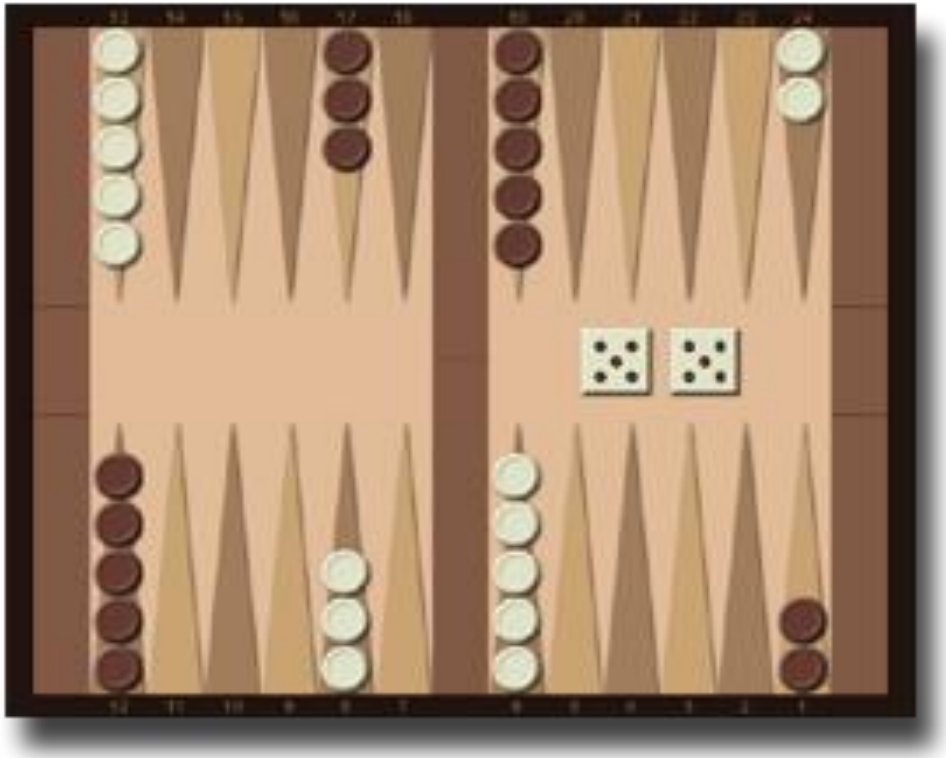
Chess



Othello/Reversi



Backgammon



Games

- Number of players
  - Single-player: Solitaire, Tetris
  - Multi-player: Go, chess, Othello
- Randomness factor
  - Deterministic: Go, chess
  - Random: backgammon, most card games, most video games

Language

- Natural Language Understanding
- Natural Language Generation
- Dialogue
- Beware of ambiguities!


TABLES ARE
FOR EATING
CUSTOMERS
ONLY
NO LOITERING

Learning

- Machine learning

  A subfield of computer science and artificial intelligence that deals with the construction and study of systems that can learn from data, rather than follow only explicitly programmed instructions.

- Examples:
  - Learning to drive an autonomous car in a novel environment
  - Learning to adjust to a user's behavior
- Types of learning:
  - Supervised: labeled examples
  - Unsupervised: no examples
  - Semi-supervised: some examples
  - By reinforcement

Interacting with the Environment

- Sensing
  - Speech
  - Video
  - Text
  - Sensors
- Acting
  - Making decisions
  - Manipulating objects

What is a Computer?

Let’s start with these easier questions….

What is a Hammer?

A hammer is an AMPLIFIER for….

What is a Phone?

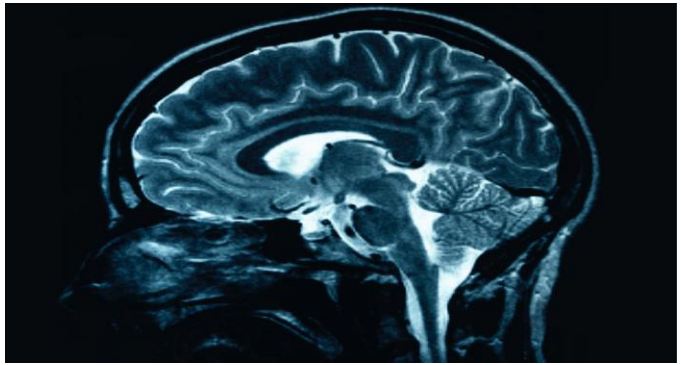
A phone is an AMPLIFIER for….

What is a Car?

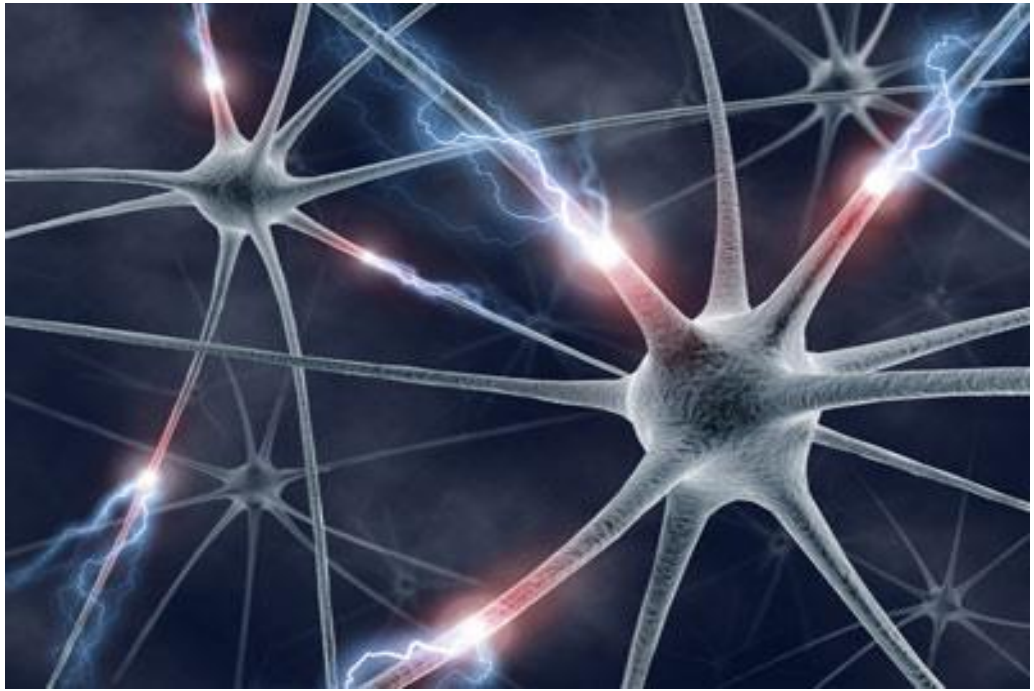
A car is an AMPLIFIER for….

What is a Computer?

A computer is an AMPLIFIER for….



The Brain!



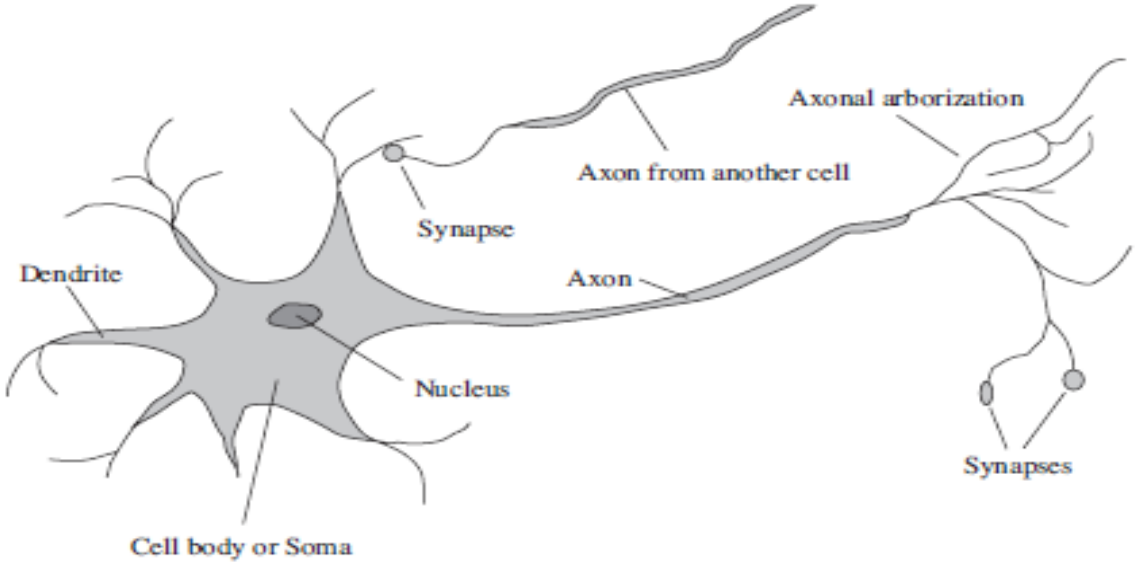


Figure 1.2 FILES: figures/neuron.eps (Tue Nov 3 16:23:13 2009). The parts of a nerve cell or neuron. Each neuron consists of a cell body, or soma, that contains a cell nucleus. Branching out from the cell body are a number of fibers called dendrites and a single long fiber called the axon. The axon stretches out for a long distance, much longer than the scale in this diagram indicates. Typically, an axon is 1 cm long (100 times the diameter of the cell body), but can reach up to 1 meter. A neuron makes connections with 10 to 100,000 other neurons at junctions called synapses. Signals are propagated from neuron to neuron by a complicated electrochemical reaction. The signals control brain activity in the short term and also enable long-term changes in the connectivity of neurons. These mechanisms are thought to form the basis for learning in the brain. Most information processing goes on in the cerebral cortex, the outer layer of the brain. The basic organizational unit appears to be a column of tissue about 0.5 mm in diameter, containing about 20,000 neurons and extending the full depth of the cortex about 4 mm in humans).

The Brain!

- 50-100B of these in a human brain
- 10,000s of connections each!
- ~10B critical pyramidal cells involved with cognition
- 1000 trillion (1 quadrillion) connections!
- Why is it so wrinkled?
  - More brain surface (cerebral cortex) can fit in our skull
- Frontal lobes oversized by mammalian standards
- Vision processing oversized
- Three times larger than next avg mammal

The Brain!

- What does it do?
- Long-term memory
  - Declarative (explicit) memory
    - knowing *what*
    - facts and events
    - conscious recall
  - Procedural (implicit) memory
    - knowing *how*
    - skills
    - unconscious recall
- Short-term memory
  - Temporary memory
    - typically 10-15 seconds
    - usually about seven items

What is AI?

Views of AI fall into four categories:

Systems that think like humans	Systems that think rationally
Systems that act like humans	Systems that act rationally

- The textbook advocates "acting rationally“.
- This is not the only approach!

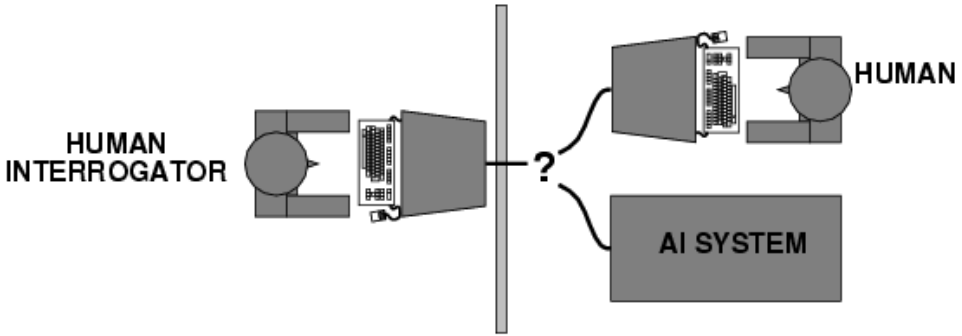
Eight Definitions of AI

Thinking Humanly	**Thinking Rationally**
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Figure 1.1 Some definitions of artificial intelligence, organized into four categories.

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



- Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
- Anticipated all major arguments against AI in following 50 years
- Suggested major components of AI: knowledge, reasoning, language understanding, learning
- The total Turing test would also involve vision and robotics

Thinking humanly: cognitive modeling

- 1960s "cognitive revolution": information-processing psychology
- The General Problem Solver – Newell and Simon – they tried not only to solve a problem but also to compare the system's reasoning process to that of a human
- Requires scientific theories of internal activities of the brain
- How to validate? Requires
    1) Predicting and testing behavior of human subjects (top-down)
    2) Direct identification from neurological data (bottom-up)
- 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
- 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:
  1. Not all intelligent behavior is mediated by logical deliberation
  2. What is the purpose of thinking? What thoughts should I have?

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 – but thinking should be in the service of rational action

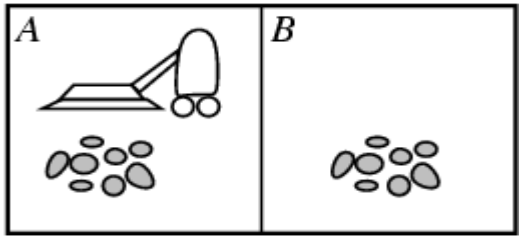
Rational Agents

- 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:

$$[f: \mathcal{P}^{\star} \rightarrow \mathcal{A}]$$

- 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
  - → Example: a polynomial algorithm for an exponential problem
  - → Satisficing!

Vacuum-cleaner world



- Percepts: location and contents, e.g., [A,Dirty]
- Actions: *Left*, *Right*, *Suck*, *NoOp*

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*

What is the **right** function?
Can it be implemented in a small agent program?

AI prehistory

• 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 engineering	Building fast computers
• Control theory	Design systems that maximize an objective function over time
• Linguistics	Knowledge representation, grammar, dialogue

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
- 1950s Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist
- 1960s First expert systems (e.g., DENDRAL)
- 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 (e.g., Winograd’s SHRDLU)

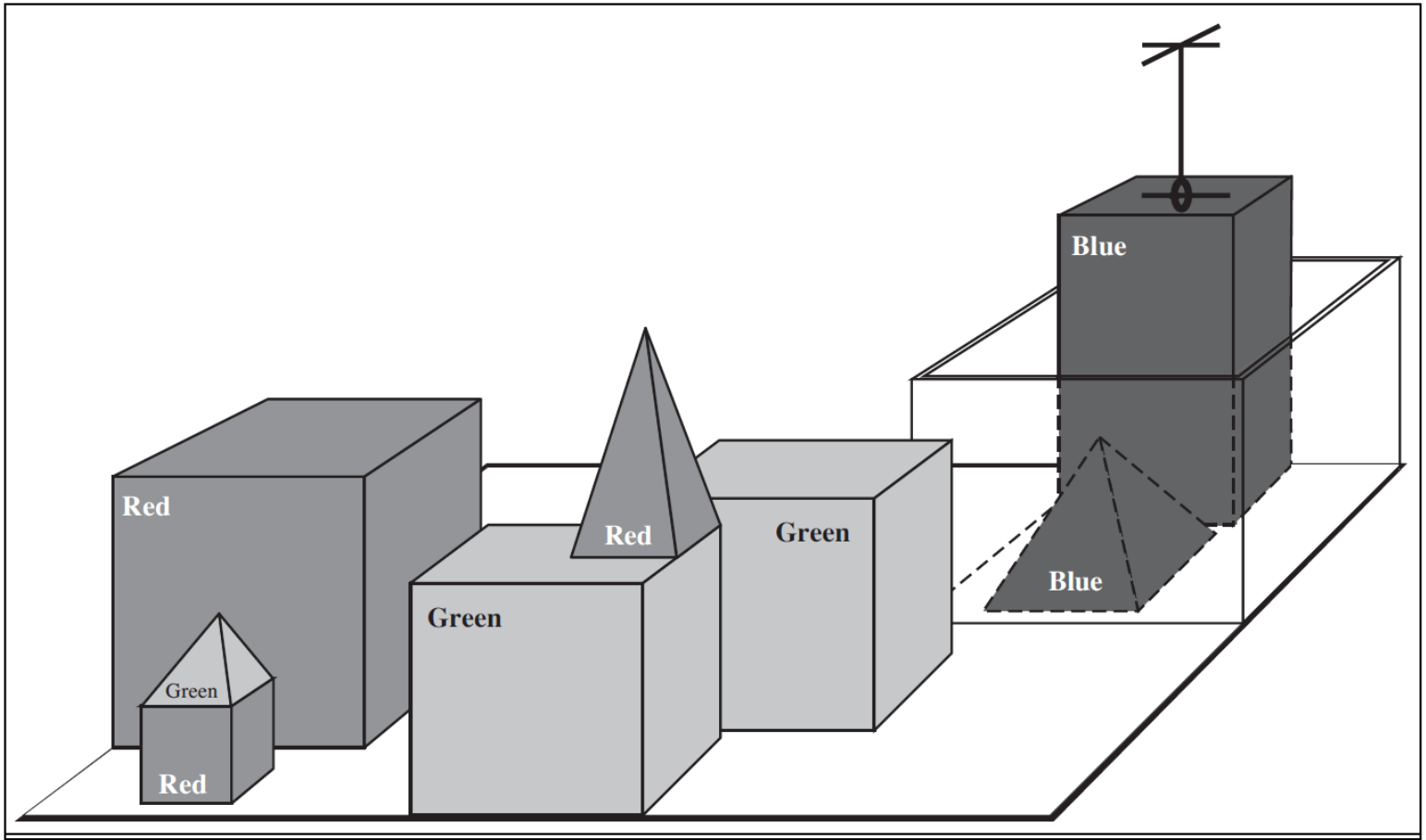


Figure 1.4 A scene from the blocks world. SHRDLU (Winograd, 1972) has just completed the command "Find a block which is taller than the one you are holding and put it in the box."

Abridged history of AI

- 1980-- AI becomes an industry
- 1986-- Neural networks return to popularity
- 1987-- AI becomes a science
- 1989-- Statistical methods, e.g., for NLP (e.g., IBM's MT system)
- 1995-- The emergence of intelligent agents
- 2010-- Big data, social media
- 2010-- "Deep Learning", practical AI (Siri, automated cars)

State of the Art

- Deep Blue defeated the reigning world chess champion Garry Kasparov in 1997
- Proved a mathematical conjecture (Robbins conjecture) unsolved for decades
- 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
- Dr. Fill can solve crossword puzzles better than most humans
- AI Knowledge based system components are embedded in many real-world applications
- Jeopardy!! Watson beats the best humans…in 2011
- Siri, Alexa, Cortana, OK Google
- Google Translate
- Facebook babi
- Google beat Lee Sedol in the game of Go in 2016

Exercise

1.14 Examine the AI literature to discover whether the following tasks can currently be solved by computers:

a. Playing a decent game of table tennis (Ping-Pong).

b. Driving in the center of Cairo, Egypt.

c. Driving in Victorville, California.

d. Buying a week's worth of groceries at the market.

e. Buying a week's worth of groceries on the Web.

f. Playing a decent game of bridge at a competitive level.

g. Discovering and proving new mathematical theorems.

h. Writing an intentionally funny story.

i. Giving competent legal advice in a specialized area of law.

j. Translating spoken English into spoken Swedish in real time.

k. Performing a complex surgical operation.

1.14

a. (ping-pong) A reasonable level of proficiency was achieved by Andersson's robot (Andersson, 1988).

b. (driving in Cairo) No. Although there has been a lot of progress in automated driving, all such systems currently rely on certain relatively constant clues: that the road has shoulders and a center line, that the car ahead will travel a predictable course, that cars will keep to their side of the road, and so on. Some lane changes and turns can be made on clearly marked roads in light to moderate traffic. Driving in downtown Cairo is too unpredictable for any of these to work.

c. (driving in Victorville, California) Yes, to some extent, as demonstrated in DARPA's Urban Challenge. Some of the vehicles managed to negotiate streets, intersections, well-behaved traffic, and well-behaved pedestrians in good visual conditions.

d. (shopping at the market) No. No robot can currently put together the tasks of moving in a crowded environment, using vision to identify a wide variety of objects, and grasping the objects (including squishable vegetables) without damaging them. The component pieces are nearly able to handle the individual tasks, but it would take a major integration effort to put it all together.

e. (shopping on the web) Yes. Software robots are capable of handling such tasks, particularly if the design of the web grocery shopping site does not change radically over time.

f. (bridge) Yes. Programs such as GIB now play at a solid level.

g. (theorem proving) Yes. For example, the proof of Robbins algebra described on page 360.

h. (funny story) No. While some computer-generated prose and poetry is hysterically funny, this is invariably unintentional, except in the case of programs that echo back prose that they have memorized.

i. (legal advice) Yes, in some cases. AI has a long history of research into applications of automated legal reasoning. Two outstanding examples are the Prolog-based expert systems used in the UK to guide members of the public in dealing with the intricacies of the social security and nationality laws. The social security system is said to have saved the UK government approximately $150 million in its first year of operation. However, extension into more complex areas such as contract law awaits a satisfactory encoding of the vast web of common-sense knowledge pertaining to commercial transactions and agreement and business practices.

j. (translation) Yes. In a limited way, this is already being done. See Kay, Gawron and Norvig (1994) and Wahlster (2000) for an overview of the field of speech translation, and some limitations on the current state of the art.

k. (surgery) Yes. Robots are increasingly being used for surgery, although always under the command of a doctor. Robotic skills demonstrated at superhuman levels include drilling holes in bone to insert artificial joints, suturing, and knot-tying. They are not yet capable of planning and carrying out a complex operation autonomously from start to finish.

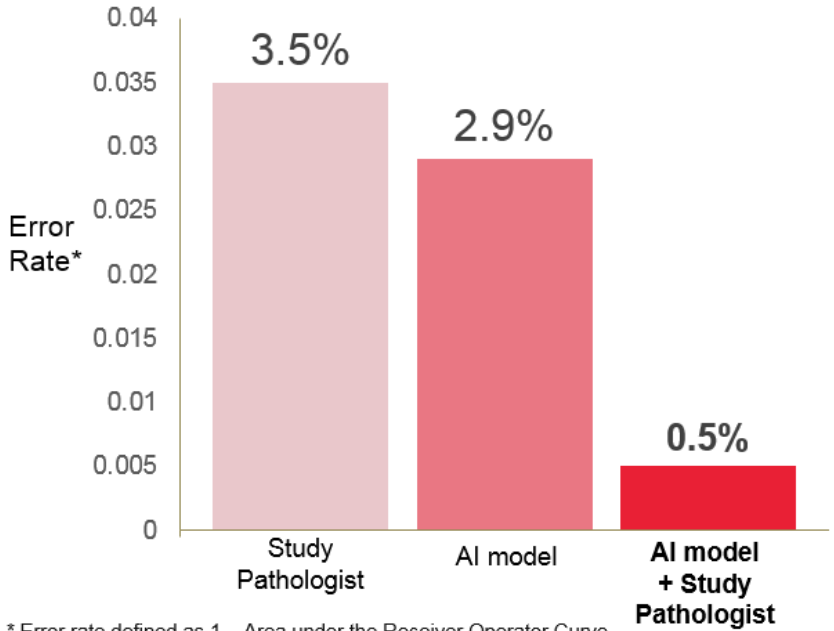
Related Courses and Journals

- Related courses at Yale
  - Natural Language Processing (Radev)
  - Computer Vision (Zucker)
  - Data Mining and Machine Learning (Lafferty, Wolf, Krishnaswamy)
  - Neural Networks (Barron)
  - Intelligent Robotics (Scaz)
- Conferences and journals
  - IJCAI, AAAI
  - AISTATS, UAI
  - ACL, NAACL, EMNLP
  - ICML, NIPS, ICLR
  - AIJ, JAIR, CL, TACL, JMLR

Other Applications of AI

- Handwriting recognition (full addresses)
- Machine translation
- Search engines
- Speech understanding
- Financial trading
- Recommendation systems
- Business logistics
- Navigation
- Fraud detection
- Autonomous cars (since 2005 – DARPA’s Grand Challenge)

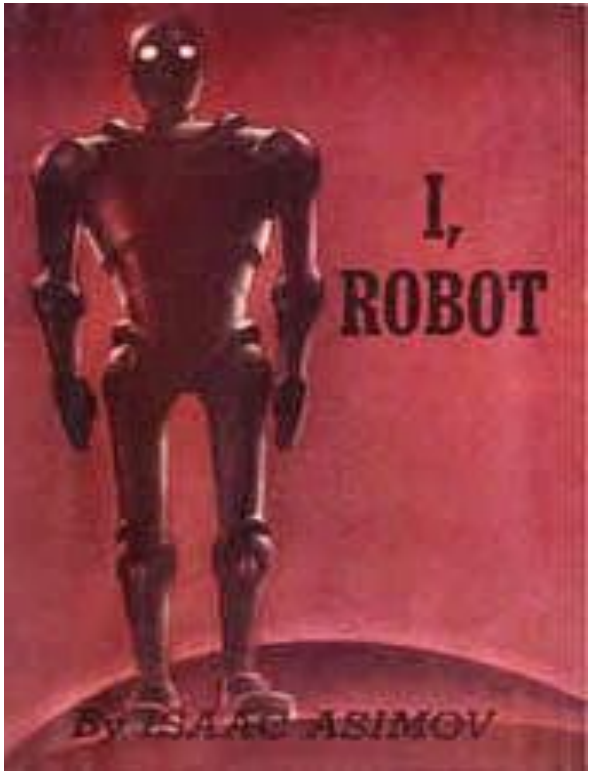
(AI + Pathologist) > Pathologist

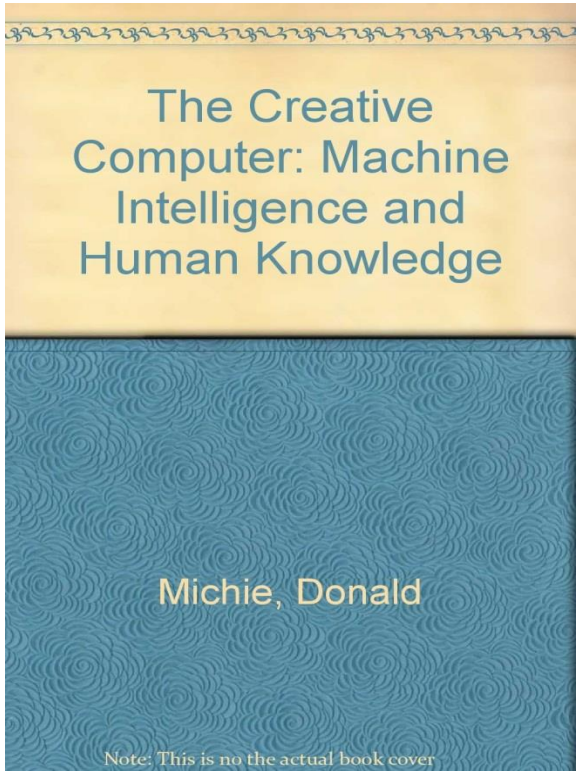


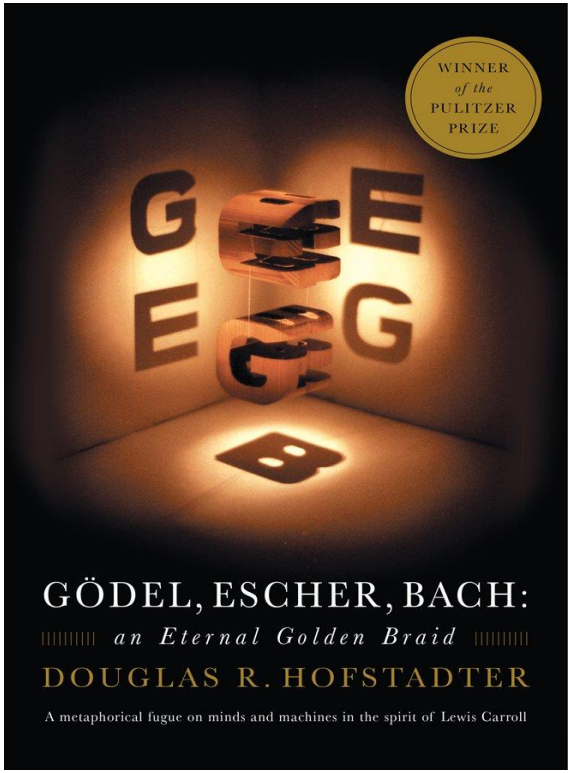
* Error rate defined as 1 – Area under the Receiver Operator Curve
** A study pathologist, blinded to the ground truth diagnoses, independently scored all evaluation slides.

https://blogs.nvidia.com/blog/2016/09/19/deep-learning-breast-cancer-diagnosis/

Readings







https://www.goodreads.com/list/show/485.Best_artificial_intelligence_books
http://www.computerworld.com/article/2488478/emerging-technology/ai-gets-its-groove-back.html

Autonomous Car Videos

- https://www.youtube.com/watch?v=-96BEoXJMs0
  - NVIDIA AI Car
- https://www.youtube.com/watch?v=NC79pdZ5Rr0
  - Neurala AI Car
- https://youtu.be/5hFvoXV9gII
  - Princeton Deep Driving
  - http://deepdriving.cs.princeton.edu/

Robot Videos

- https://www.youtube.com/watch?v=bivS1qQKHec
  - Beijing RoboCup Challenge
- https://www.youtube.com/watch?v=XgRw42oHN-Y
  - Robocup 2016
- https://www.youtube.com/watch?v=rVlhMGQgDkY
  - Boston Dynamics Atlas
- https://www.youtube.com/watch?v=X_VLR7vU-8c
  - Shipping Warehouse Robots

Other Videos

- https://www.youtube.com/watch?v=vFr3K2DORc8
  - AlphaGo vs. Lee Sedol
- https://www.youtube.com/watch?v=-O01G3tSYpU
  - A DARPA perspective
- https://www.youtube.com/watch?v=21EiKfQYZXc
  - Andrew Ng - Artificial Intelligence is the New Electricity
- https://www.youtube.com/watch?v=vQXAsdMa_8A
  - Demis Hassabis – Towards General Artificial Intelligence
- https://www.youtube.com/watch?v=8nt3edWLgIg
  - Sam Harris
- https://www.youtube.com/watch?v=LSHZ_b05W7o
  - Daddy's Car: a song composed by Artificial Intelligence - in the style of the Beatles
- https://www.youtube.com/watch?v=V1eYniJ0Rnk
  - Google DeepMind's Deep Q-learning playing Atari Breakout
- https://www.youtube.com/watch?v=TnUYcTuZJpM
  - Google Deep Mind

Important points about AI

- Problem solving and decision making
  - Maximizing utility
- Very difficult tasks
  - Computational complexity (even at the level of constants)
  - Heuristics and knowledge are needed
  - However, the definition changes over time
- Not necessarily perfect solutions
  - Satisficing
  - Uncertainty
- Societal impact
  - Affecting billions
  - Ethics

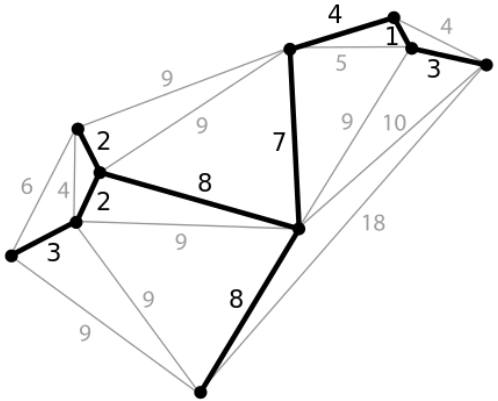
AI Method

- Real life problem -> model -> algorithms
- Example: autonomous car navigation
- Separate modeling (stay in lane/switch lane) from algorithms
- Machine learning approach: labeled training data given as input to learning algorithm
- Generalization (training to test)

Optimization

min f(x)

- Discrete optimization
  - Dynamic programming
  - Integer programming
- Continuous optimization
  - Gradient descent



Takeaways

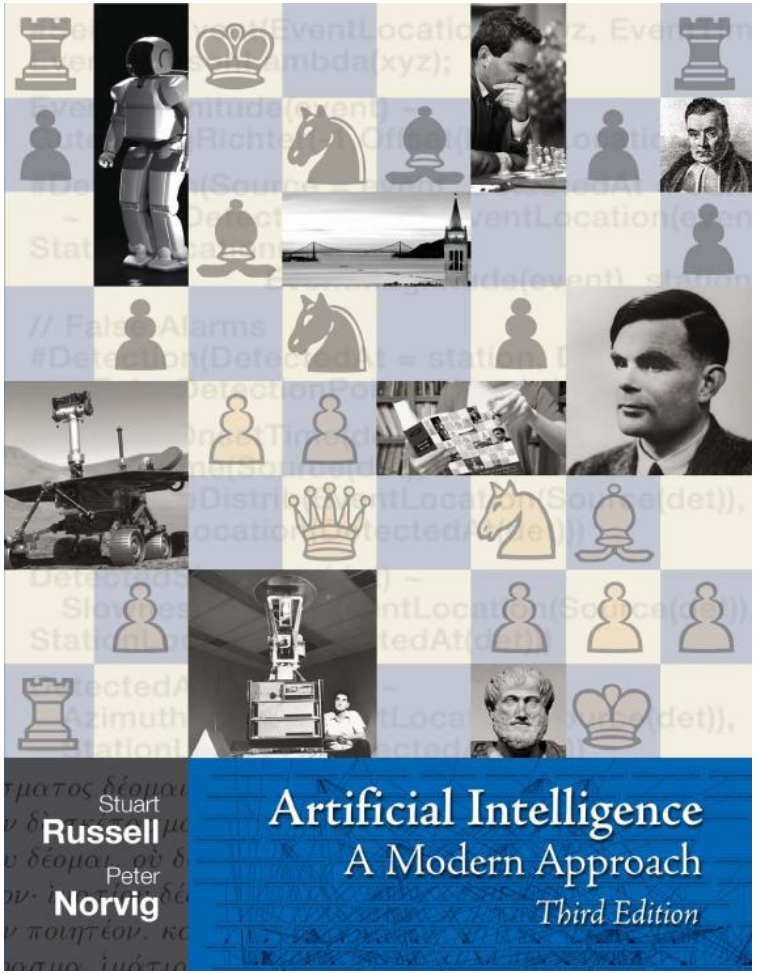
- Tractable approaches to exponential problems
- Using knowledge, experience, heuristics
- Learning, Logic, Language, Games
- Social impact: jobs, security, ethics

Artificial Intelligence

Class Logistics

Textbook

- Stuart Russell and Peter Norvig *Artificial Intelligence: A Modern Approach* Prentice Hall, 2009, Third Edition



Book Chapters

- Introduction and Agents (chapters 1,2)
- Search (chapters 3,5,6)
- Logic (chapters 7,8,9)
- Knowledge Representation (chapter 12)
- Uncertainty (chapters 13,14)
- Learning (chapter 18)
- Natural Language Processing (chapter 22,23)
- Other topics
  - Autonomous Cars, Deep Learning, Reinforcement Learning, etc.

Course Information

- Official prerequisites:
  - After CPSC 201 and 202 (or by permission of the instructor)
- Description:
  - Introduction to artificial intelligence research, focusing on reasoning and perception. Topics include knowledge representation, predicate calculus, temporal reasoning, vision, robotics, planning, and learning.
- Skills
  - Quantitative Reasoning

Course Dates

- AUG
  - 31
- SEP
  - 5 7 12 14 19 21 26 28
- OCT
  - 3 5 10 12 17 24 26 31
- NOV
  - 2 7 9 14 16 28 30
- DEC
  - 5 7
- Important dates:
  - Midterm (per registrar) Friday 10/27
  - Last day of classes Friday 12/8
  - Finals 12/15 – 12/20

Syllabus

- Introduction
  - Introduction to AI, Python for AI, Agent-based view of AI
- Problem Solving and Search
  - Problem Solving and Search, Informed Search, Heuristic Search, Advanced Search, Game Playing, Adversarial Search, Genetic Algorithms, Constraint Satisfaction
- Language and Logic
  - Logical Agents, Predicate Logic, First Order Logic, Inference, Knowledge Representation, Natural Language Processing and Communication, Speech Processing (if time)
- Reasoning under Uncertainty
  - Quantifying Uncertainty, Intro to uncertainty, Probabilistic Reasoning, Bayesian Networks
- Learning
  - Learning from Examples, Classification and Clustering, Markov Decision Processes, Neural Networks, Reinforcement Learning, Autonomous Cars

Useful Background

- Linear algebra
  - vectors and matrices
- Probabilities
  - random variables
  - discrete and continuous distributions
  - Bayes' theorem
- Programming
  - Python in a UNIX environment.
  - text manipulation

Grading

- Assignments
  - Programming assignments (50%)
  - Other assignments (10%)
  - Midterm (15%)
  - Final (20%)
  - Class participation (5%)

Assignments (draft list)

- HW 0: Introduction to the Course Environment
- HW 1: Mathematical Models (problem set)
- HW 2: Search (Pacman*)
- HW 3: Game Playing (Othello)
- HW 4: Language and Logic (Deep Learning and NLP)
- HW 5: Classification (Autonomous Cars)
- HW 6: Reinforcement Learning (AI Gym)

*Pac-Man is a registered trademark of Namco-Bandai Games, used here for educational purposes

How to get the most out of the class?

- Attend the lectures and study the slides
  - Course syllabus + slides = road map
  - Some material may not be found in any of the readings
- Hands on experience
  - Implement what you've learned
- Ask questions in and after class

Questions?

- Use the right channels for communications
  - Piazza (not Canvas)
- In special cases (e.g., sickness, regrading), email the instructors
  - Include [CPSC470] or [CPSC570] or [AI Class] in the subject line
- Office Hours:
  - Instructor: Fridays 2-4 pm in room 319, 17 Hillhouse

Courses at Other Places

- Brick-and-Mortar
  - Stanford (Percy Liang)
  - Berkeley (Pieter Abbeel and Dan Klein)
- Online
  - Deep Learning (Andrew Ng) on Coursera

Research in AI

- Conferences:
  - AAAI, IJCAI
- Journals:
  - JAIR, Artificial Intelligence
- University centers:
  - Berkeley, Stanford, MIT, CMU, Columbia, Cornell, Michigan, Texas, Edinburgh, Oxford, Cambridge…
- Industrial research sites:
  - Google (+ Brain, DeepMind), Facebook, MSR, IBM, Baidu…

Academic Honesty

- Unless otherwise specified in an assignment all submitted work must be your own, original work. Any excerpts, statements, or phrases from the work of others must be clearly identified as a quotation, and a proper citation provided.
- Any violation of the University's policy on Academic and Professional Integrity will result in serious penalties, which might range from failing an assignment, to failing a course, to being expelled from the program.
- Violations of academic and professional integrity will be reported to Student Affairs. Consequences impacting assignment or course grades are determined by the faculty instructor; additional sanctions may be imposed.

Student Mental Health and Wellbeing

- Yale University is committed to advancing the mental health and wellbeing of its students.
- If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available.

Students with Disabilities

- If you think you need an accommodation for a disability, please let me know at your earliest convenience.
- Some aspects of this course, the assignments, the in-class activities, and the way we teach may be modified to facilitate your participation and progress.
- I will treat any information that you provide in as confidential a manner as possible.

Programming Language

- The programming assignments will be in Python.
- You are expected to either know Python already or to learn it on your own.
- The AIMA code base has been installed on the **Zoo** machines
  - http://www.cs.berkeley.edu/~russell/code/doc/install.html
- Other machines may also be available.

Submitting Assignments

- In the absence of a prior emailed authorization from the instructor, you should turn in your assignments electronically by 11:59:59 PM on the due date. For each day (or fraction of a day) that your submission is late, it will be penalized 10%, for a maximum of 30%. After three days, the assignment will be given a score of zero.
- You will need to hand in the source code for the project, relevant documentation, and a script of a test run of your program to show that it actually works on the Zoo machines.

Integrity Policies

- Collaboration policy:
  - You may discuss the course material and the textbook with other students. You may also discuss the *requirements* of the assignments. However, you cannot get help with the assignments and exams themselves in oral or written form from anyone. If you are unsure about this policy, ask the instructors.
- Honesty policy:
  - We will be using high grade plagiarism detection code
  - Do not copy other people's code or misrepresent it as yours, period.

Specifics

- Coding and write up should be done independently
- Do not show your work to anyone
- Do not look at anyone’s work
- Do not use existing web code (e.g., github)

Grading Appeals

- If you have a question about your grade on a particular assignment (or exam), write a short email to the TA in charge of that assignment.
- Please submit any such requests within a week of receiving your grade.

Job Prospects

- Software Engineering
- Finance
- Government
- Teaching
- AI Research
  - (see next slide)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