Introduction

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Course information

- Grading
  - Lecture quizzes: up to 10 points, 1 for each perfect quiz
  - Working at the practices: up to $6 \times 3 = 18$ points
  - Two assignments: up to $3 + 9 = 12$ points
  - Exam: up to 20 points
  - Grades:
    - 50-60 excellent (5)
    - 40-49 good (4)
    - 30-39 satisfactory (3)
    - 20-29 pass (2)
    - 0-19 fail (1)
- The course webpage is on Canvas
- Textbook: S. Russel, P. Norvig: Artificial Intelligence. A modern approach.
- Academic integrity

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AI today

- Artificial intelligence has become an overloaded term
- We are in a period of AI frenzy
  - Just like many times before
  - Hype/bust cycles have been alternating since the very beginning
- AI is used as a synonym of
  - machine learning
  - deep learning, neural networks
  - software

  Artificial intelligence is now such a big catch-all term that practically any computer program that automatically does something is referred to as AI.

  Forbes, 2018
- RoboCup 2019 final: `https://www.youtube.com/watch?v=4_BWQl91p9Y`

What is AI?

- Trying to answer the question: What is required for machines to exhibit intelligence?
- Next obvious question: What does it mean to exhibit intelligence?
- Very difficult question, Turing dodges it with the imitation game

Strong vs Weak AI

- Strong AI
  - Artificial *general* intelligence
    - *General* is very important: the same intelligence can solve different problems
    - AlphaGo beat everyone in Go, but couldn't do anything in the real world (simulation)
  - Artificial consciuosness: self-aware machine
  - Computational theory of mind: our minds are computer programs
    - John Searle: Chinese room argument
    - Nobody supposes that the computational model of rainstorms in London will leave us all wet.
- Weak AI
  - Make computers solve specific interesting problems which – at the moment – people can do better

AI is the frontier of computing

- AI has always been at the frontier of what's possible
- The need to write cutting edge programs pushed for novel tools and influenced software engineering tremendously
- Some examples invented for AI and Lisp (many by John McCarthy and his lab at MIT)
  - if/then/else constructs
  - garbage collection
  - dynamic typing
  - recursive function calls
  - IDEs
  - first class functions
  - lexical closures
  - time sharing (servers, cloud)
- Most modern and successful programming languages (e.g., Python) are close to Lisp
- John McCarthy served on the board of the ALGOL 60 committee, proposed if/then/else and recursion

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Origins

- Capture the processes of human thought
- Ancient origins: Aristotle, Euclid, etc.
- Mathematical logic (Leibniz, Boole, Frege)
- Principia Mathematica: a formal treatment of the foundations of mathematics
  - 1+1=2 proved after several hundred pages
- David Hilbert: can all of mathematical reasoning be formalized?
  - No (Godel's theorem)
  - But: Turing machines, lambda calculus can imitate any mathematical deduction within limits
  - Thinking machines may be possible!

Before AI

- 1943: McCulloch and Pitts describe how artificial neurons could perform logical functions and the first neural network
- Marvin Minsky – their student – built the first neural network
- 1950: Computing Machinery and Intelligence - Turing test

For we can easily understand a machine's being constituted so that it can utter words, and even emit some responses to action on it of a corporeal kind, which brings about a change in its organs; for instance, if touched in a particular part it may ask what we wish to say to it; if in another part it may exclaim that it is being hurt, and so on. But it never happens that it arranges its speech in various ways, in order to reply appropriately to everything that may be said in its presence, as even the lowest type of man can do.

Rene Descartes – 1637

Dartmouth Summer Research Project on Artificial Intelligence

- The founding event of AI
- Organized by John McCarthy
- He coined the name for the field: "Artificial Intelligence"
- Ran for eight weeks

we will concentrate on a problem of devising a way of programming a calculator to form concepts and to form generalizations

Dartmouth Summer Research Project on Artificial Intelligence

- Some attendees:
  - **John McCarthy**: father of AI, developer of Lisp
  - **Ray Solomonoff**: the inventor of algorithmic probability and founder of algorithmic information theory
  - **Marvin Minsky**: co-wrote the book that showed the XOR limitation of perceptrons
  - Claude Shannon: the father of information theory (1948)
  - John Nash: Nobel Prize for 28 page PhD thesis on non-cooperative games (Nash equilibrium)
  - W. S. McCulloch: first mathematical model of neural networks with Pitts
  - Arthur Samuel: coined the term “Machine learning”
  - Nat Rochester: wrote the first assembler
  - David Sayre: partly developed FORTRAN
  - Herbert Simon: Nobel and Turing Prize in economics and Turing award

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Predictions

- 1958 – Herbert Simon and Allen Newel: within ten years a digital computer will be the world's chess champion
- 1965 – Herbert 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 from three to eight years we will have a machine with the general intelligence of an average human being.
- 2014 – Ray Kurzweil: artificial intelligence will reach human levels by around 2029
- 2017 – Hanson Robotics CEO: Oh yeah, she is basically alive. (about the Sophie robot)

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Initial successes

- 1955 – Logic Theorist: proved 38 of the 52 theorems in Principia Mathematica, found more elegant proofs for some
- 1958 – Rosenblatt's perceptron
- 1966 – ELIZA: the first chatterbot, could fool some people into believing it was human
  - I am ***** $\rightarrow$ Why do you think you are ******?
  - Weizenbaum was horrified when someone wrote a "computer program which can conduct psychotherapeutic dialogue" based on Eliza, intended for therapy
- 1968-70 – microworlds as in physics, blocks world, SHRDLU
  - could be instructed in natural language

SHRDLU conversation example

Person: Pick up a big red block.
Computer: OK.
Person: Grasp the pyramid.
Computer: I DON'T UNDERSTAND WHICH PYRAMID YOU MEAN.
Person (changing their mind): Find a block which is taller than the one you are holding and put it into the box.
Computer: BY "IT", I ASSUME YOU MEAN THE BLOCK WHICH IS TALLER THAN THE ONE I AM HOLDING.
Computer: OK.
Person: What does the box contain?
Computer: THE BLUE PYRAMID AND THE BLUE BLOCK.
Person: What is the pyramid supported by?
Computer: THE BOX.
Person: How many blocks are not in the box?
Computer: FOUR OF THEM.
Person: Is at least one of them narrower than the one which i told you to pick up?
Computer: YES, THE RED CUBE.

AI winter

- 1966: ALPAC report on progress in machine translation, ending all support after 20 million dollars spent
- 1969: Criticism of perceptrons by Marvin Minsky, XOR problem
- 1973: Lighthill report: utter failure to achieve the grandiose objectives, dismantling of AI research in the UK
- Problems
  - Not enough computational power: in some NLP applications, 20 words would fit into the memory
  - Commonsense knowledge and reasoning is very hard, the knowledge acquisition bottleneck
  - Moravec's paradox: "it is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility"

AI winter?

- 1970 – Seppo Linnainma: reverse mode of automatic differentiation (backpropagation)
- 1974 – Paul Werbos: backpropagation for neural nets
- 1975 – Minsky: frames $\rightarrow$ inheritance in OOP
- 1982 – Paul Werbos: backpropagation applied to nonlinear functions

Boom

- 1980s – Expert systems; XCON saved 40 million dollars annually
- 1985 – Companies are spending over a billion dollars on AI, Lisp Machines
- Cyc project: common sense ontology
- Fifth generation computer project in Japan: massively concurrent logic programming
- 1986 – Backpropagation gains recognition

Bust

- 1987: The market for AI hardware (Lisp machines) collapses (general purpose computers like Intel x86 surpassed them in speed)
- Expert systems turn out to be too brittle and difficult to maintain
- Funding for AI cut
- Goals of fifth generation computer project not met
- Over 300 AI companies shut down, go bankrupt, or acquired

Today

- 2006 – Geoffrey Hinton: pretraining many-layered neural networks
- 2012 – AlexNet wins the ImageNet challenge by a large margin
- Deep learning
  - Lots of data
  - Lots of computational power (GPUs, now TPUs)
- Speech recognition: works very well
- Advances in automatic text generation
- Valid ethical concerns
  - Debate whether OpenAI should release the full GTP-2 model (fake news)
  - Deepfakes
- One of the main goals is self-driving cars
- 2019 – Yoshua Bengio, Geoffrey Hinton, and Yann LeCun are awarded the Turing prize (Jürgen Schmidhuber?)

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Natural language processing

- **Dialogue systems**
- Summarization
- Machine translation
- Automatic speech recognition
- Text to speech
- Web search
- Question answering
- Spam filtering

Computer vision

- Object recognition
- Image classification
- Image search
- Face recognition
- Optical Character Recognition (OCR)
- Detecting manufacturing defects
- Tracking objects (e.g., pedestrians or vehicles for self-driving cars)
- Medical computer vision

Games

- Games have traditionally been an interesting application area and source of benchmark problems for AI
- Video games: search for pathfinding, evolutionary algorithms, recently neural networks
- 1997: Deep Blue beats Gary Kasparov
  - Custom VLSI chips to run alpha-beta search in parallel
  - The 259th most powerful supercomputer in the world
  - 11.38 GFLOPS (today: RTX 3070: 20 TFLOPS, $500)
  - Search between six and eight moves deep, 20 or more moves wide
  - Many parameters in the evaluation function were learned by the system by analyzing thousands of games
  - Hand-crafted knowledge by grandmasters (e.g., opening book)
  - Kasparov suggested that human chess players intervened $\rightarrow$ Deep Blue passed the "chess Turing test"

Games

- 2016: AlphaGo beats Lee Sedol
  - Much higher branching factor (250) than chess (35) $\rightarrow$ traditional AI like alpha-beta pruning is very difficult
  - Monte Carlo Tree Search (based on minimax search)
    - Invented for Go and the go-to algorithm since 2006
    - Play the game randomly many-many times and weigh the nodes in the game tree
    - Total War: Rome II's campaign AI also uses MCTS
  - Deep learning: Estimate position value, policy
  - 1920 CPUs and 280 GPUs $\rightarrow$ 48 TPUs
  - Lee Sedol is the only human player who beat AlphaGo

After humanity spent thousands of years improving our tactics, computers tell us that humans are completely wrong... I would go as far as to say not a single human has touched the edge of the truth of Go.

Ke Jie, 1st ranked Go player in the world

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Part I: Search

- Search algorithms
  - Local search
  - Backtrack
  - Graph search: BFS, DFS, $A^\star$
  - Adversarial search: minimax, alpha-beta
  - Evolutionary algorithms
- Some applications of search algorithms
  - Backtrack: Solving puzzles, logic programming
  - Local search: numerical optimization, training neural networks
  - $A^\star$ search: pathfinding in most video games
  - Adversarial search: board games like five-in-a-row, chess
  - Evolutionary algorithms: neuroevolution (Mario)

Part II: Learning

- Approaches
  - Supervised learning
  - Unsupervised learning
  - (Reinforcement learning)
- Some applications of machine learning
  - Supervised learning: speech recognition
  - Unsupervised learning: clustering in Google search
  - RL: Robots for packing, sorting products

Practice

- Implementing the ideas of AI in Python
- Topics
  - Coding in Python
  - Local search: sliding puzzle
  - Backtrack: 8-queens problem
  - Graph search: labyrinth
  - Supervised learning
  - Unsupervised learning

AI is the fun part of computing

> *I think that it's extraordinarily important that we in computer science keep fun in computing. When it started out, it was an awful lot of fun. Of course, the paying customers got shafted every now and then, and after a while we began to take their complaints seriously. We began to feel as if we really were responsible for the successful, error-free perfect use of these machines. I don't think we are. I think we're responsible for stretching them, setting them off in new directions, and keeping fun in the house.*

Alan J. Perlis, from the Foreword of Structure and Interpretation of Computer Programs