Artificial Intelligence

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What is intelligence?

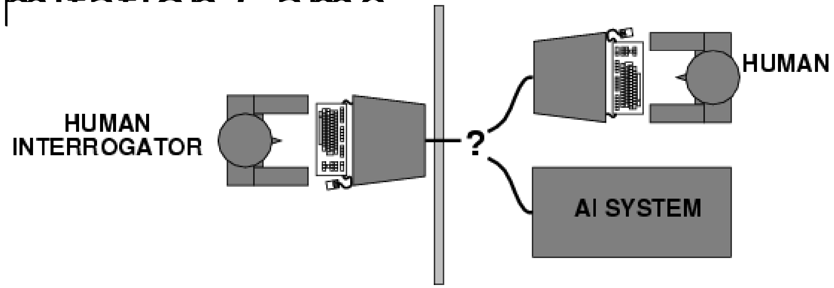
- The ability to acquire and apply knowledge and skills.
- The ability to solve problems.
- The ability to perceive, interpret and understand.
- The ability to learn, emotional knowledge, reason, plan, creativity, critical thinking

Artificial Intelligence

- Historically four approaches to artificial intelligence have been followed, each by different people with different methods:
  - Acting Humanly
  - Thinking Humanly
  - Acting rationally
  - Thinking rationally

Acting humanly: Turing Test

- Modeling exactly how humans actually act.
- Turing (1950) "Computing machinery and intelligence":
- "Can machines think?" → "Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game



- A computer passes the test if a human

  interrogator, after posing some written questions, cannot tell whether the written responses come from a person or from a computer.

Acting humanly: Turing Test

- The computer would need to possess the following capabilities:
  - natural language processing to enable it to communicate successfully in English;
  - knowledge representation to store what it knows or hears;
  - automated reasoning to use the stored information to answer questions and to draw new conclusions;
  - Machine learning to adapt to new circumstances and to detect and extrapolate patterns.

Thinking Humanly

- “The exciting new effort to make computers think ...machines with minds, in the full and literal sense.
- [The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning.
- Modeling exactly how humans actually think, cognitive models of human reasoning.

Acting rationally: rational agent

- Rational behavior: Doing that was is expected to maximize one’s “utility function” in this world.
- An agent is an entity that perceives and acts. A rational agent

  acts rationally.
- This course is about designing rational agents
- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance.

Thinking Rationally

- “The study of mental faculties through the use of computational models.”
- “The study of the computations that make it possible to perceive, reason, and act.”
- Modeling how ideal agents “should think”
  - models of “rational” thought (formal logic)
  - note: humans are often not rational!

Academic Disciplines important to AI.

- 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 — neurons as information processing units.
- Psychology/ Cognitive Science — how do people behave, perceive, process information, represent knowledge.
- Computer engineering — building fast computers
- Control theory — design systems that maximize an objective function over time
- Linguistics — knowledge representation, grammar

History of AI

- 1943 McCulloch & Pitts: Boolean circuit model of brain
- 1950 Turing's "Computing Machinery and Intelligence"
- 1956 Dartmouth meeting: "Artificial Intelligence" adopted
- 1952—69 Look, Ma, no hands!
- 1950s Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
- 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
- 1980-- AI becomes an industry
- 1986-- Neural networks return to popularity
- 1987-- AI becomes a science
- 1995-- The emergence of intelligent agents

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
- No hands across America (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
- `Proverb` solves crossword puzzles better than most humans
- Best vehicle in Darpa challenge made it 7 miles into the desert...

Consider what might be involved in building a “smart” computer….

- What are the “components” that might be useful?
  - Fast hardware?
  - Foolproof software?
  - Chess-playing at grandmaster level?
  - Speech interaction?
    - speech synthesis
    - speech recognition
    - speech understanding
  - Image recognition and understanding ?
  - Learning?
  - Planning and decision-making?

Can we build hardware as complex as the brain?

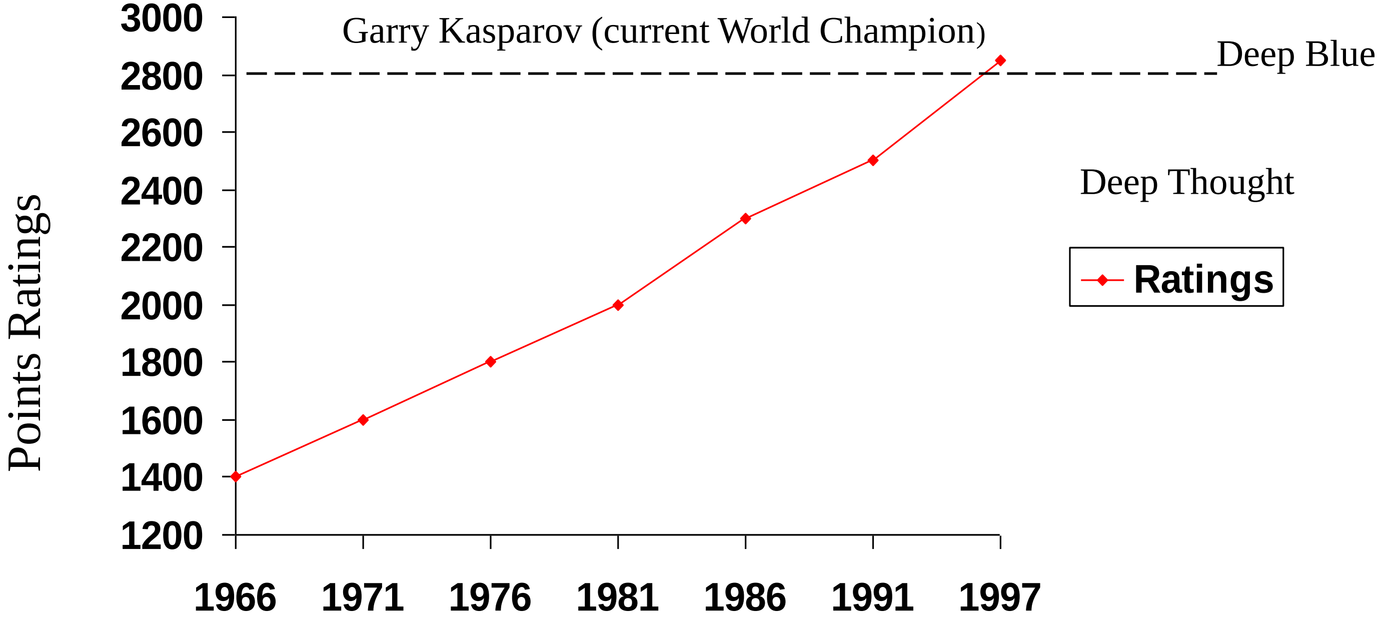
- How complicated is our brain?
  - a neuron, or nerve cell, is the basic information processing unit
  - estimated to be on the order of 10^{12} neurons in a human brain
  - many more synapses (10^{14}) connecting these neurons
  - cycle time: 10^{-3} seconds (1 millisecond)
- How complex can we make computers?
  - 10^6 or more transistors per CPU
  - supercomputer: hundreds of CPUs, 10^9 bits of RAM
  - cycle times: order of 10^{-8} seconds
- Conclusion
  - **YES**: in the near future we can have computers with as many basic processing elements as our brain, but with
    - far fewer interconnections (wires or synapses) than the brain
    - much faster updates than the brain
  - **but** building hardware is very different from making a computer behave like a brain!

Must an Intelligent System be Foolproof?

- A “foolproof” system is one that never makes an error:
  - Types of possible computer errors
    - hardware errors, e.g., memory errors
    - software errors, e.g., coding bugs
    - “human-like” errors
  - Clearly, hardware and software errors are possible in practice
  - what about “human-like” errors?
- An intelligent system can make errors and still be intelligent
  - humans are not right all of the time
  - we learn and adapt from making mistakes
    - e.g., consider learning to surf or ski
      - we improve by taking risks and falling
      - an intelligent system can learn in the same way
- Conclusion:
  - **NO**: intelligent systems will not (and need not) be foolproof

Can Computers play Humans at Chess?

- Chess Playing is a classic AI problem
  - well-defined problem
  - very complex: difficult for humans to play well



- Conclusion: YES: today's computers can beat even the best human

Can Computers Talk?

- This is known as “speech synthesis”
  - translate text to phonetic form
    - e.g., “fictitious” -> fik-tish-es
  - use pronunciation rules to map phonemes to actual sound
    - e.g., “tish” -> sequence of basic audio sounds
- Difficulties
  - sounds made by this “lookup” approach sound unnatural
  - sounds are not independent
    - e.g., “act” and “action”
    - modern systems (e.g., at AT&T) can handle this pretty well
  - a harder problem is emphasis, emotion, etc
    - humans understand what they are saying
    - machines don’t: so they sound unnatural
- Conclusion: NO, for complete sentences, but YES for individual words

Can Computers Recognize Speech?

- Speech Recognition:
  - mapping sounds from a microphone into a list of words.
  - Hard problem: noise, more than one person talking, occlusion, speech variability,..
  - Even if we recognize each word, we may not understand its meaning.
- Recognizing single words from a small vocabulary
  - systems can do this with high accuracy (order of 99%)
  - e.g., directory inquiries
    - limited vocabulary (area codes, city names)
    - computer tries to recognize you first, if unsuccessful hands you over to a human operator
    - saves millions of dollars a year for the phone companies

Recognizing human speech (ctd.)

- Recognizing normal speech is much more difficult
  - speech is continuous: where are the boundaries between words?
    - e.g., “John’s car has a flat tire”
  - large vocabularies
    - can be many thousands of possible words
    - we can use **context** to help figure out what someone said
      - try telling a waiter in a restaurant:
        “I would like some dream and sugar in my coffee”
  - background noise, other speakers, accents, colds, etc
  - on normal speech, modern systems are only about 60% accurate

- Conclusion: NO, normal speech is too complex to accurately recognize, but YES for restricted problems
  - (e.g., recent software for PC use by IBM, Dragon systems, etc)

Can Computers Understand speech?

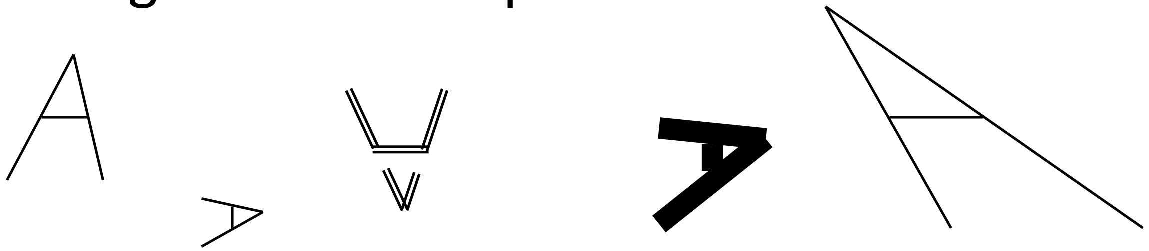
- Understanding is different to recognition:
  - “Time flies like an arrow”
    - assume the computer can recognize all the words
    - but how could it understand it?
      - 1. time passes quickly like an arrow?
      - 2. command: time the flies the way an arrow times the flies
      - 3. command: only time those flies which are like an arrow
      - 4. “time-flies” are fond of arrows
    - only 1. makes any sense, but how could a computer figure this out?
      - clearly humans use a lot of implicit commonsense knowledge in communication
- Conclusion: NO, much of what we say is beyond the capabilities of a computer to understand at present

Can Computers Learn and Adapt ?

- Learning and Adaptation
  - consider a computer learning to drive on the freeway
  - we could code lots of rules about what to do
  - or we could let it drive and steer it back on course when it heads for the embankment
    - systems like this are under development (e.g., Daimler Benz)
    - e.g., RALPH at CMU
      - in mid 90's it drove 98% of the way from Pittsburgh to San Diego without any human assistance
  - Machine learning allows computers to learn to do things without explicit programming
- Conclusion: YES, computers can learn and adapt, when presented with information in the appropriate way

Can Computers "see"?

- Recognition v. Understanding (like Speech)
    - Recognition and Understanding of Objects in a scene
        - look around this room
        - you can effortlessly recognize objects
        - human brain can map 2d visual image to 3d "map"
- Why is visual recognition a hard problem?



- Conclusion: mostly NO: computers can only "see" certain types of objects under limited circumstances: but YES for certain constrained problems (e.g., face recognition)

Can Computers plan and make decisions?

- Intelligence
  - involves solving problems and making decisions and plans
  - e.g., you want to visit your cousin in Boston
    - you need to decide on dates, flights
    - you need to get to the airport, etc
    - involves a sequence of decisions, plans, and actions
- What makes planning hard?
  - the world is not predictable:
    - your flight is canceled or there's a backup on the 405
  - there are a potentially huge number of details
    - do you consider all flights? all dates?
      - no: commonsense constrains your solutions
  - AI systems are only successful in constrained planning problems
- Conclusion: NO, real-world planning and decision-making is still beyond the capabilities of modern computers
  - exception: very well-defined, constrained problems: mission planning for satelites.

Summary of State of AI Systems in Practice

- Speech synthesis, recognition and understanding
  - very useful for limited vocabulary applications
  - unconstrained speech understanding is still too hard
- Computer vision
  - works for constrained problems (hand-written zip-codes)
  - understanding real-world, natural scenes is still too hard
- Learning
  - adaptive systems are used in many applications: have their limits
- Planning and Reasoning
  - only works for constrained problems: e.g., chess
  - real-world is too complex for general systems
- Overall:
  - many components of intelligent systems are “doable”
  - there are many interesting research problems remaining

Intelligent Systems in Your Everyday Life

- Post Office
  - automatic address recognition and sorting of mail
- Banks
  - automatic check readers, signature verification systems
  - automated loan application classification
- Telephone Companies
  - automatic voice recognition for directory inquiries
  - automatic fraud detection,
  - classification of phone numbers into groups
- Credit Card Companies
  - automated fraud detection, automated screening of applications
- Computer Companies
  - automated diagnosis for help-desk applications

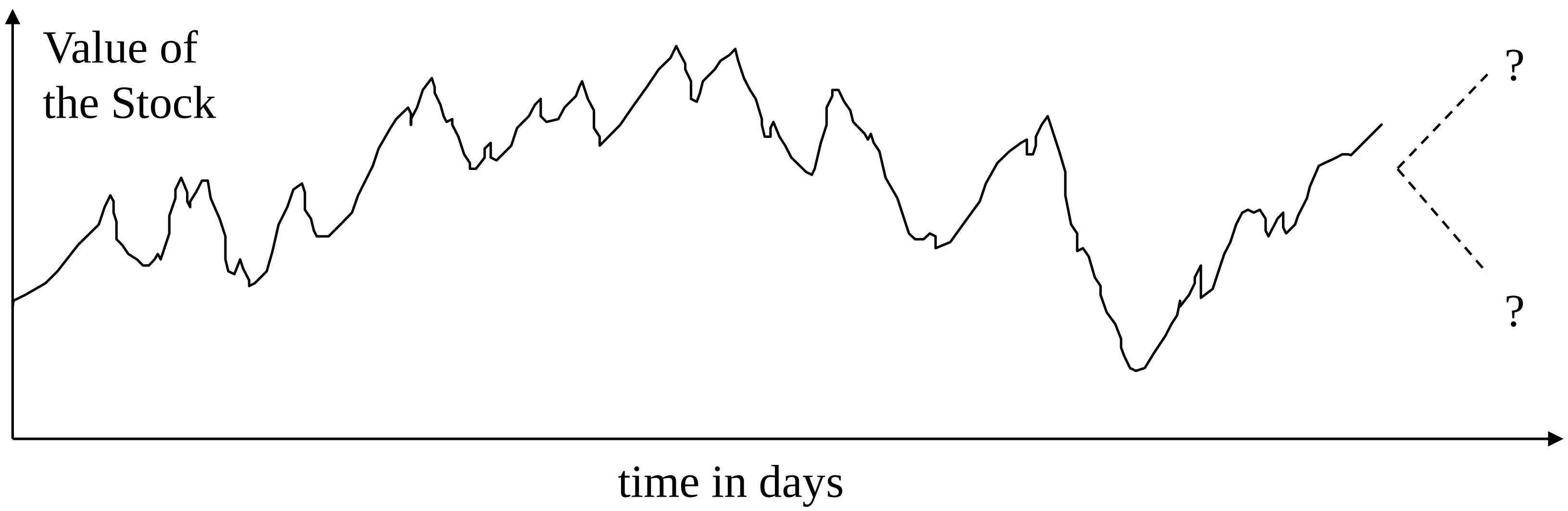
AI Applications: Consumer Marketing

- Have you ever used any kind of credit/ATM/store card while shopping?
  - if so, you have very likely been "input" to an AI algorithm
- All of this information is recorded digitally
- Companies like Nielsen gather this information weekly and search for patterns
  - general changes in consumer behavior
  - tracking responses to new products
  - identifying customer segments: targeted marketing, e.g., they find out that consumers with sports cars who buy textbooks respond well to offers of new credit cards.
  - Currently a very hot area in marketing
- How do they do this?
  - Algorithms ("data mining") search data for patterns
  - based on mathematical theories of learning
  - completely impractical to do manually

AI Applications: Identification Technologies

- ID cards
  - e.g., ATM cards
  - can be a nuisance and security risk:
    - cards can be lost, stolen, passwords forgotten, etc
- Biometric Identification
  - walk up to a locked door
    - camera
    - fingerprint device
    - microphone
  - computer uses your biometric signature for identification
    - face, eyes, fingerprints, voice pattern

AI Applications: Predicting the Stock Market



- The Prediction Problem
  - given the past, predict the future
  - very difficult problem!
  - we can use learning algorithms to learn a predictive model from historical data
    - `prob(increase at day t+1 | values at day t, t-1,t-2....,t-k)`
  - such models are routinely used by banks and financial traders to manage portfolios worth millions of dollars

AI-Applications: Machine Translation

- Language problems in international business
  - e.g., at a meeting of Japanese, Korean, Vietnamese and Swedish investors, no common language
  - or: you are shipping your software manuals to 127 countries
  - solution; hire translators to translate
  - would be much cheaper if a machine could do this!
- How hard is automated translation
  - very difficult!
  - e.g., English to Russian
    - "The spirit is willing but the flesh is weak" (English)
    - "the vodka is good but the meat is rotten" (Russian)
  - not only must the words be translated, but their meaning also!
- Nonetheless....
  - commercial systems can do alot of the work very well (e.g.,restricted vocabularies in software documentation)
  - algorithms which combine dictionaries, grammar models, etc.
  - see for example babelfish.altavista.com

End of Slides