MEET HAL

http://www.youtube.com/watch?v=LE1F7d6f1Qk

2001: A Space Odyssey

- classic science fiction movie from 1969

HAL

- part of the story centers around an intelligent computer called HAL
- HAL is the “brains” of an intelligent spaceship
- in the movie, HAL can
  - speak easily with the crew
  - see and understand the emotions of the crew
  - navigate the ship automatically
  - diagnose on-board problems
  - make life-and-death decisions
  - display emotions

In 1969 this was science fiction: is it still science fiction?

DIFFERENT TYPES OF ARTIFICIAL INTELLIGENCE

Modeling exactly how humans actually think
- cognitive models of human reasoning

Modeling exactly how humans actually act
- models of human behavior (what they do, not how they think)

Modeling how ideal agents "should think"
- models of "rational" thought (formal logic)
- note: humans are often not rational!

Modeling how ideal agents "should act"
- rational actions but not necessarily formal rational reasoning
- i.e., more of a black-box/engineering approach

Modern AI focuses on the last definition
- we will also focus on this "engineering" approach
- success is judged by how well the agent performs

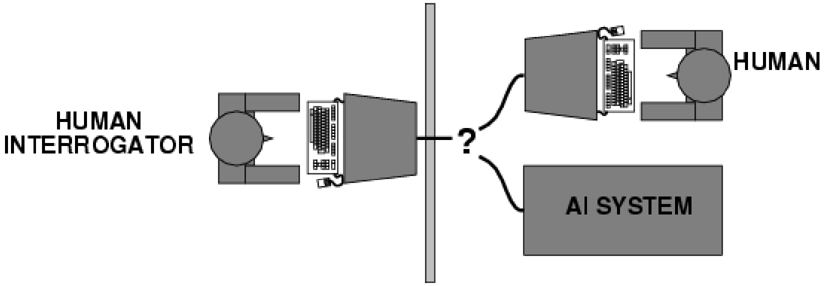
-- modern methods are also inspired by cognitive & neuroscience (how people think).

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



Suggested major components of AI:

- knowledge representation
- reasoning,
- language/image understanding,
- learning

Can you think of a theoretical system that could beat the Turing test yet you wouldn't find it very intelligent?

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

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

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, rational economic agents
Neuroscience	neurons as information processing units.

Psychology/ how do people behave, perceive, process Cognitive
Science 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
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

Stanford vehicle in Darpa challenge completed autonomously a 132 mile desert track in 6 hours 32 minutes.

CONSIDER WHAT MIGHT BE INVOLVED IN BUILDING A "INTELLIGENT" 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^{11} 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

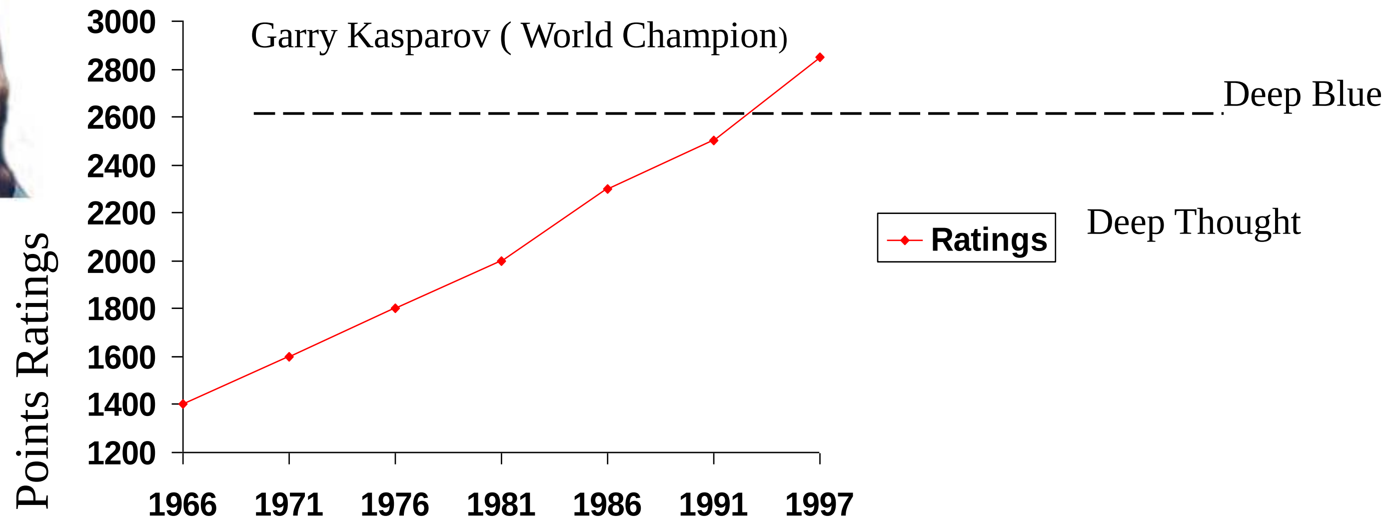
Conclusion:

- **NO**: intelligent systems will not (and need not) be foolproof

CAN COMPUTERS PLAY HUMANS AT CHESS?

Chess Playing is a classic AI problem

- ell-defined problem
- ry 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: YES, 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 tens of 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
- and/or we could have it learn from experience

Darpa's Grand Challenge. Stanford's "Stanley" drove 150 without supervision in the Majove dessert

- **machine learning** allows computers to learn to do things without explicit programming

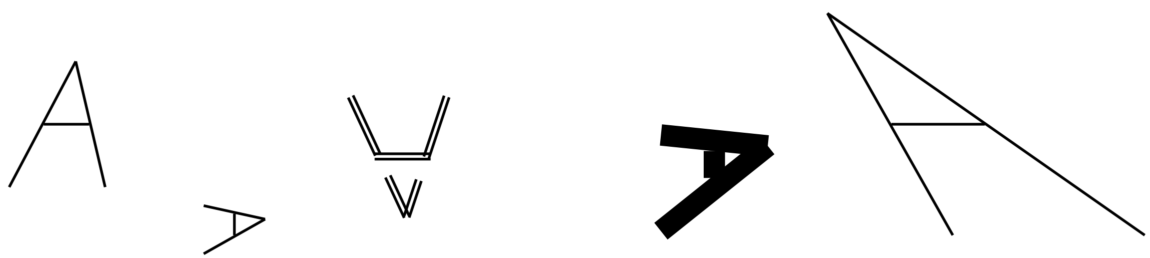
Conclusion: YES, computers can learn and adapt, when presented with information in the appropriate way

CAN COMPUTERS "SEE"?

Recognition v. Understanding (like Speech)

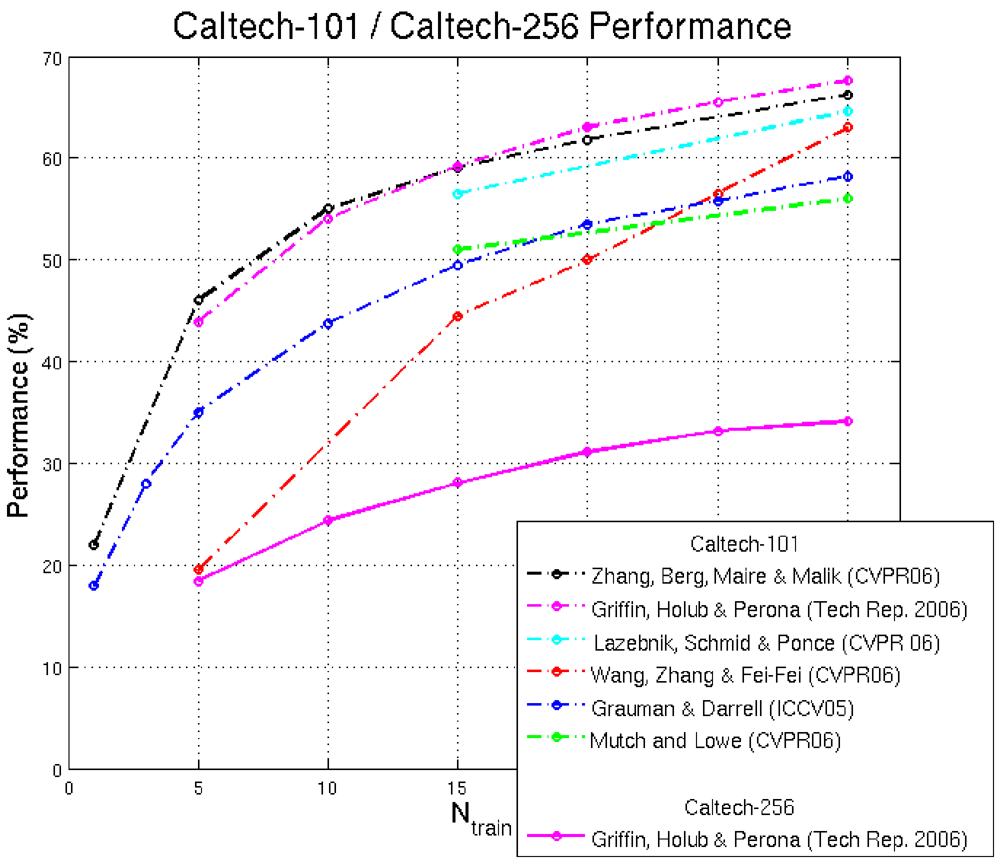
- Recognition and Understanding of Objects in a scene
  - look around this room
  - you can effortlessly recognize objects
  - human brain can map 2d visual image to 3d "map"

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)

In the computer vision community research compete to improve recognition performance on standard datasets



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 is 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.

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

Credit Card Companies

- automated fraud detection

Computer Companies

- automated diagnosis for help-desk applications

Netflix:

- movie recommendation

Google:

- Search Technology

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

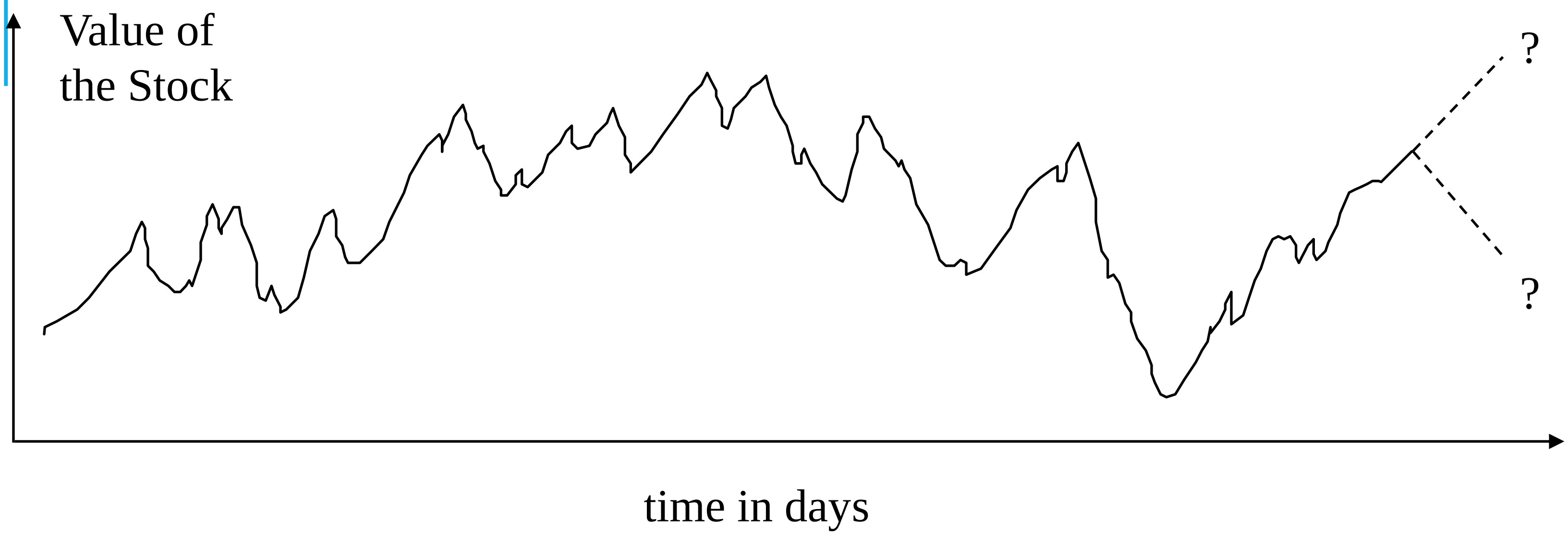
ID cards

- 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
  - iris scan
- computer uses your biometric signature for identification
  - face, eyes, fingerprints, voice pattern, iris 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

SUMMARY OF TODAY'S LECTURE

Artificial Intelligence involves the study of:

- automated recognition and understanding of speech, images, etc
- learning and adaptation
- reasoning, planning, and decision-making

AI has made substantial progress in

- recognition and learning
- some planning and reasoning problems

AI Applications

- improvements in hardware and algorithms => AI applications in industry, finance, medicine, and science.

AI Research

- many problems still unsolved: AI is a fun research area!