Introduction to Artificial Intelligence

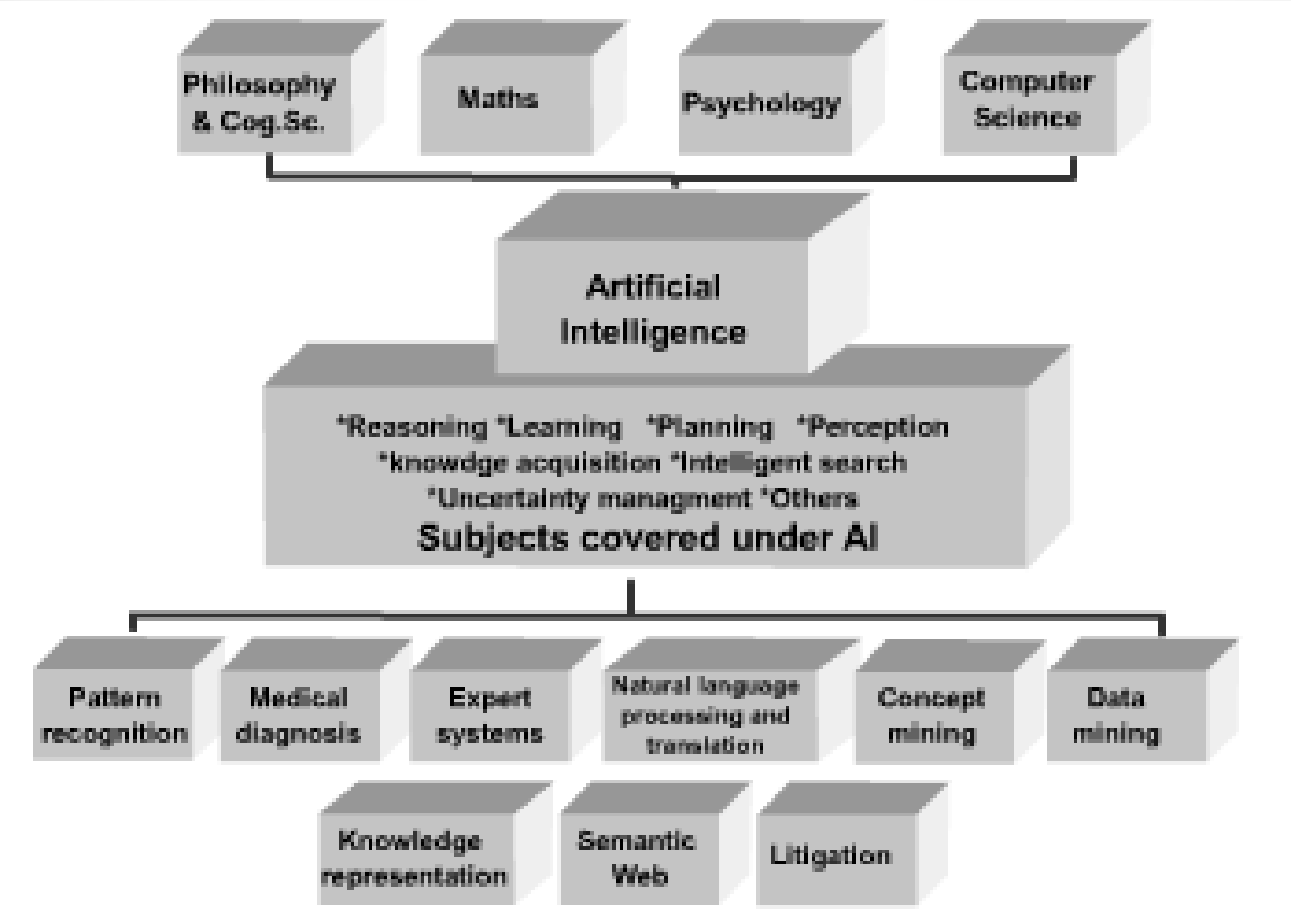
Agnieszka Nowak - Brzezińska

Goals of this Course

- This class is a broad introduction to artificial intelligence (AI)
    - AI is a very broad field with many subareas
        - We will cover many of the primary concepts/ideas
        - But in 15 weeks we can't cover everything
- Class Web page
    - http://zsi.tech.us.edu.pl/~nowak/bien/index.html/

Today's Lecture

- What is intelligence? What is artificial intelligence?
- A very brief history of AI
  - Modern successes: Stanley the driving robot
- An AI scorecard
  - How much progress has been made in different aspects of AI
- AI in practice
  - Successful applications
- The rational agent view of AI



Philosophy & Cog.Sc.
Maths
Psychology
Computer Science
Artificial Intelligence
*Reasoning *Learning *Planning *Perception
*knowdge acquisition *Intelligent search
*Uncertainty managment *Others
Subjects covered under AI
Pattern recognition
Medical diagnosis
Expert systems
Natural language processing and translation
Concept mining
Data mining
Knowledge representation
Semantic Web
Litigation

What is Artificial Intelligence?

Some Definitions (I)

The exciting new effort to make computers think …
machines with minds,
in the full literal sense.

Haugeland, 1985

(excited but not really useful)

Some Definitions (II)

The study of mental faculties through the use of computational models.

Charniak and McDermott, 1985

A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes.

Schalkoff, 1990

(Applied psychology & philosophy?)

Some Definitions (III)

The study of how to make computers do things at which, at the moment, people are better.

Rich & Knight, 1991

(I can almost understand this one).

Outline of the Course

- Knowledge representation:
  - propositional logic and first-order logic
  - inference in Expert Systems
  - Fuzzy logic
  - Rough set
  - Machine learning: classification trees
  - Neural networks
  - Ohers ?

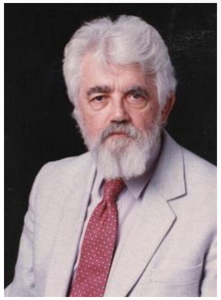
What is Intelligence?

- Intelligence:
  - “the capacity to learn and solve problems” (Websters dictionary)
  - in particular,
    - *the ability to solve novel problems*
    - *the ability to act rationally*
    - *the ability to act like humans*

- Artificial Intelligence
  - build and understand intelligent entities or agents
  - 2 main approaches: “engineering” versus “cognitive modeling”

What is Artificial Intelligence?

(John McCarthy, Stanford University)



- **What is artificial intelligence?**
  It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.

- **Yes, but what is intelligence?**
  Intelligence is the computational part of the ability to achieve goals in the world. Varying kinds and degrees of intelligence occur in people, many animals and some machines.

- **Isn't there a solid definition of intelligence that doesn't depend on relating it to human intelligence?**
  Not yet. The problem is that we cannot yet characterize in general what kinds of computational procedures we want to call intelligent. We understand some of the mechanisms of intelligence and not others.

- **More in: http://www-formal.stanford.edu/jmc/whatisai/node1.html**

What's involved in Intelligence?

- Ability to interact with the real world
  - to perceive, understand, and act
  - e.g., speech recognition and understanding and synthesis
  - e.g., image understanding
  - e.g., ability to take actions, have an effect

- Reasoning and Planning
  - modeling the external world, given input
  - solving new problems, planning, and making decisions
  - ability to deal with unexpected problems, uncertainties

- Learning and Adaptation
  - we are continuously learning and adapting
  - our internal models are always being "updated"
    - e.g., a baby learning to categorize and recognize animals

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/ 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: early beginnings
    - McCulloch & Pitts: Boolean circuit model of brain
- 1950: Turing
    - Turing's "Computing Machinery and Intelligence“
- 1956: birth of AI
    - Dartmouth meeting: "Artificial Intelligence“ name adopted
- 1950s: initial promise
    - Early AI programs, including
    - Samuel's checkers program
    - Newell & Simon's Logic Theorist
- 1955-65: “great enthusiasm”
    - Newell and Simon: GPS, general problem solver
    - Gelertner: Geometry Theorem Prover
    - McCarthy: invention of LISP

History of AI

- 1966—73: Reality dawns
  - Realization that many AI problems are intractable
  - Limitations of existing neural network methods identified
    - Neural network research almost disappears

- 1969—85: Adding domain knowledge
  - Development of knowledge-based systems
  - Success of rule-based expert systems,
    - E.g., DENDRAL, MYCIN
    - But were brittle and did not scale well in practice

- 1986-- Rise of machine learning
  - Neural networks return to popularity
  - Major advances in machine learning algorithms and applications

- 1990-- Role of uncertainty
  - Bayesian networks as a knowledge representation framework

- 1995-- AI as Science
  - Integration of learning, reasoning, knowledge representation
  - AI methods used in vision, language, data mining, etc

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

Different Types of Artificial Intelligence

1. Modeling exactly how humans actually think
2. Modeling exactly how humans actually act
3. Modeling how ideal agents “should think”
4. Modeling how ideal agents “should act”

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

What's involved in Intelligence?

- Ability to interact with the real world
  - to perceive, understand, and act
  - e.g., speech recognition and understanding and synthesis
  - e.g., image understanding
  - e.g., ability to take actions, have an effect

- Reasoning and Planning
  - modeling the external world, given input
  - solving new problems, planning, and making decisions
  - ability to deal with unexpected problems, uncertainties

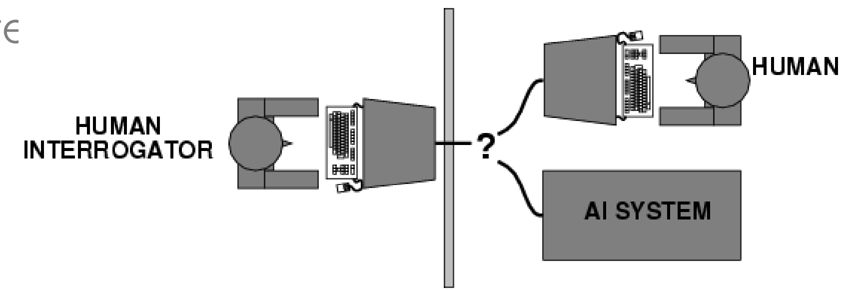
- Learning and Adaptation
  - we are continuously learning and adapting
  - our internal models are always being "updated"
    - e.g., a baby learning to categorize and recognize animals

What's involved in Intelligence? (again)

- Perceiving, recognizing, understanding the real world
- Reasoning and planning about the external world
- Learning and adaptation
- So what general principles should we use to achieve these goals?

Acting humanly: Turing test

- Turing (1950) "Computing machinery and intelligence"
- "Can machines think?" → "Can machines behave intelligently?"
- Operational te Game



- Suggests major components required for AI:
  - knowledge representation
  - reasoning,
  - language/image understanding,
  - learning

* Question: is it important that an intelligent system act like a human?

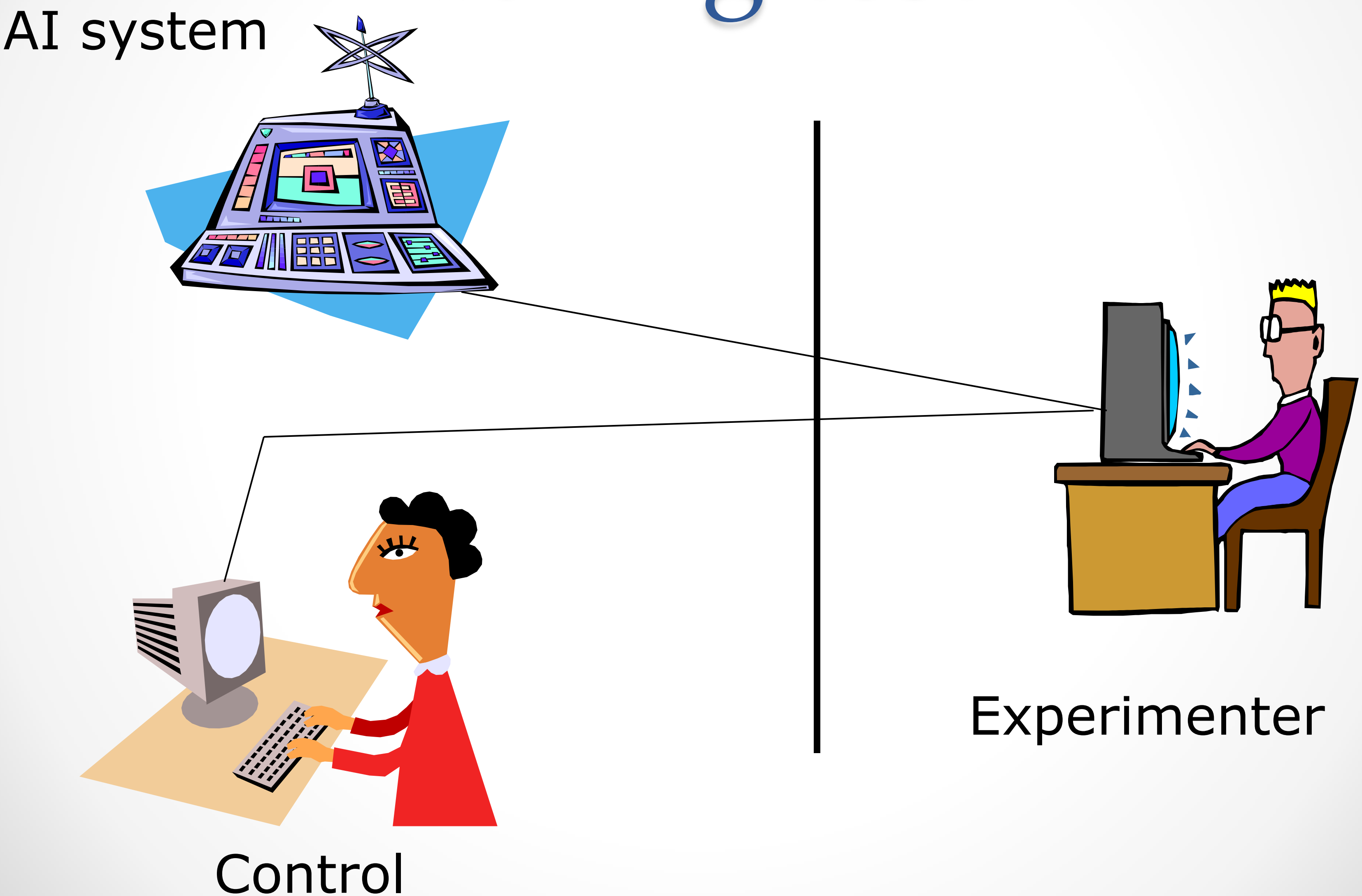
The Origins of AI

- 1950 Alan Turing's paper, *Computing Machinery and Intelligence*, described what is now called "The Turing Test".

- Turing predicted that in about fifty years "an average interrogator will not have more than a 70 percent chance of making the right identification after five minutes of questioning".

- 1957 Newell and Simon predicted that "Within ten years a computer will be the world's chess champion."

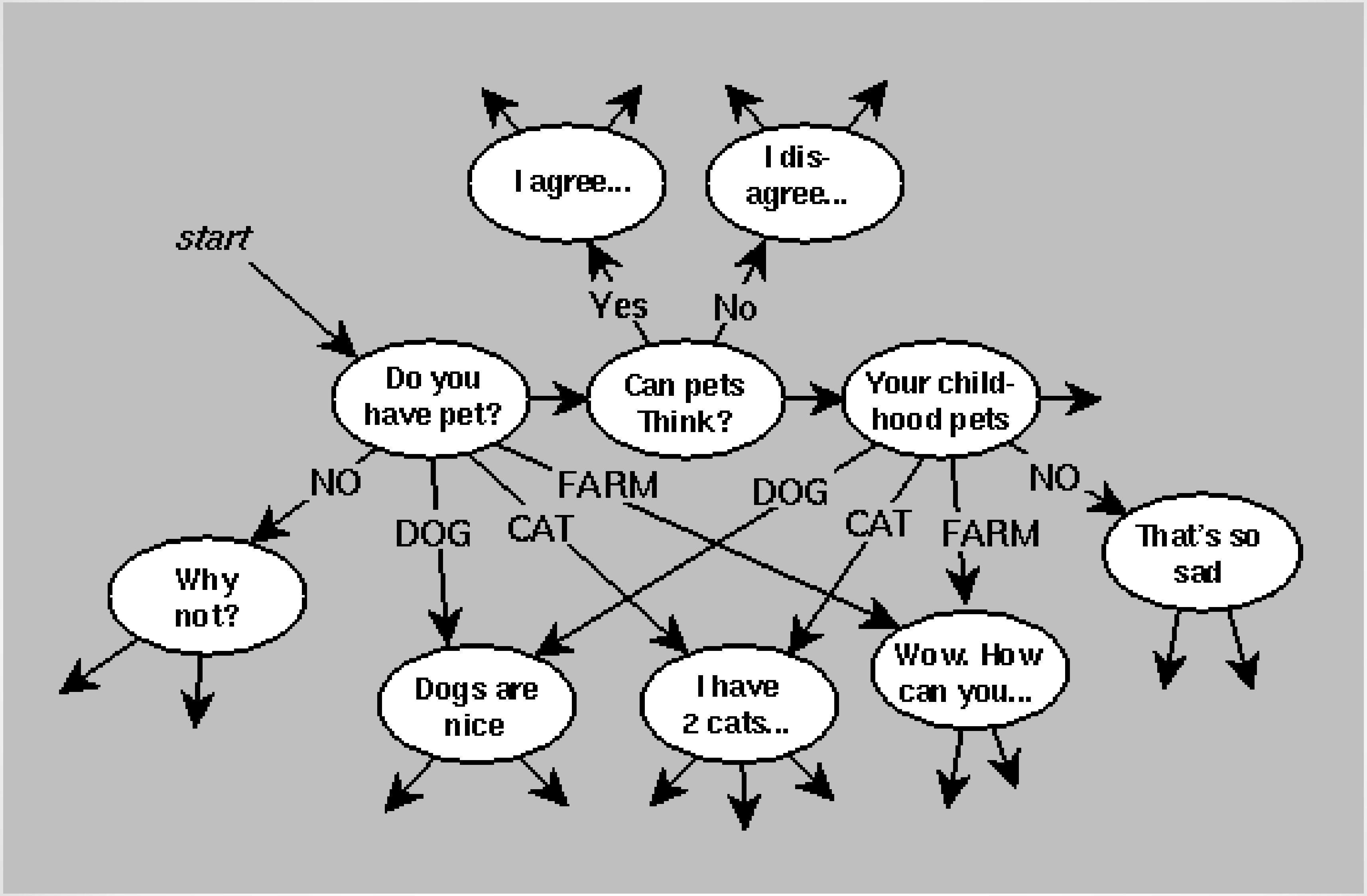
Turing test




computer
computer
?

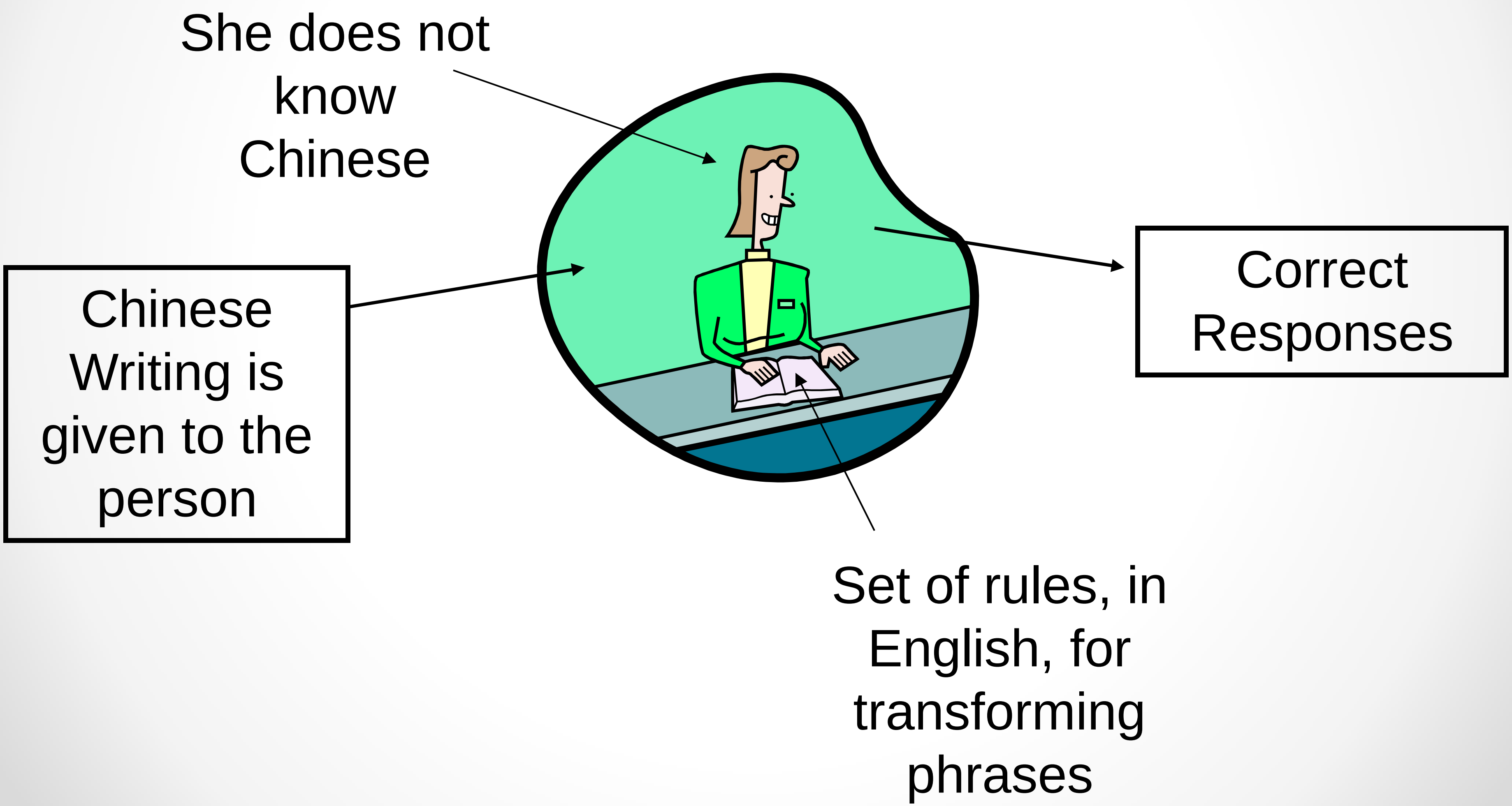
Eliza, 1965

- Patient: You are like my father in some ways.
- Doctor: What resemblance do you see?
- Patient : You are not very aggressive.
- Doctor : What makes you think I am not very aggressive?
- Patient : You don’t argue with me.
- Doctor : Why do you think I don’t argue with you?
- Patient : You are afraid of me.
- Doctor : Does it please you to believe I am afraid of you?
- Patient : My father is afraid of everybody.
- Doctor : What else comes to mind when you think of your father?
- Patient : Bullies.



start
Do you have pet?
Can pets Think?
Yes
No
I agree...
I dis-agree...
Your child-hood pets
NO
DOG
CAT
FARM
Why not?
Dogs are nice
I have 2 cats...
Wow. How can you...
That's so sad

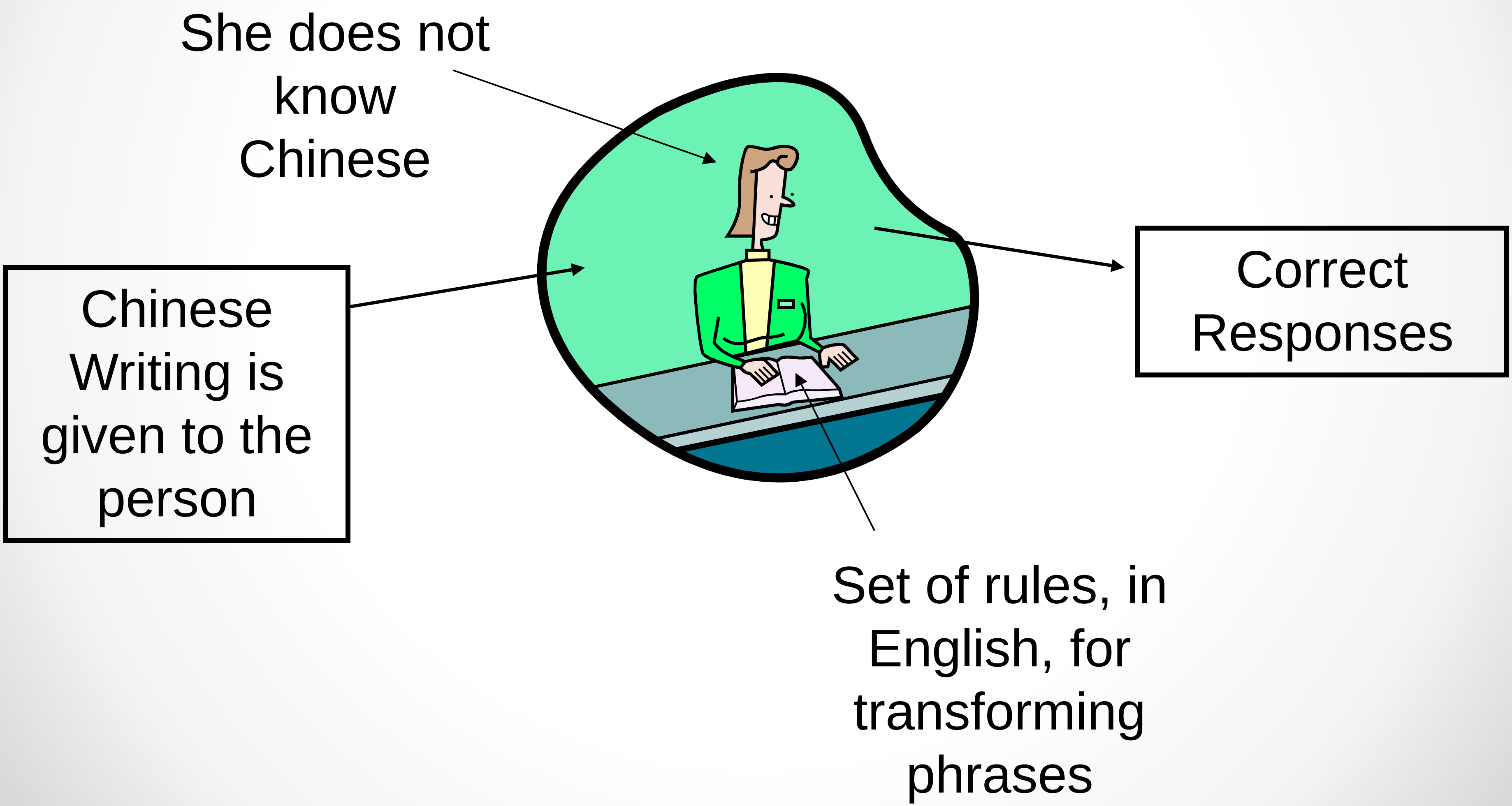
The Chinese Room



The Chinese Room

- So imagine an individual is locked in a room and given a batch of Chinese writing.
- The person locked in the room does not understand Chinese. Next he is given more Chinese writing and a set of rules (in English which he understands) on how to collate the first set of Chinese characters with the second set of Chinese characters.
- Suppose the person gets so good at manipulating the Chinese symbols and the rules are so good, that to those outside the room it appears that the person understands Chinese.
- Searle's point is that, he doesn't really understand Chinese, it really only following a set of rules.
- Following this argument, a computer could never be truly intelligent, it is only manipulating symbols that it really doesn't understand the semantic context.

The Chinese Room

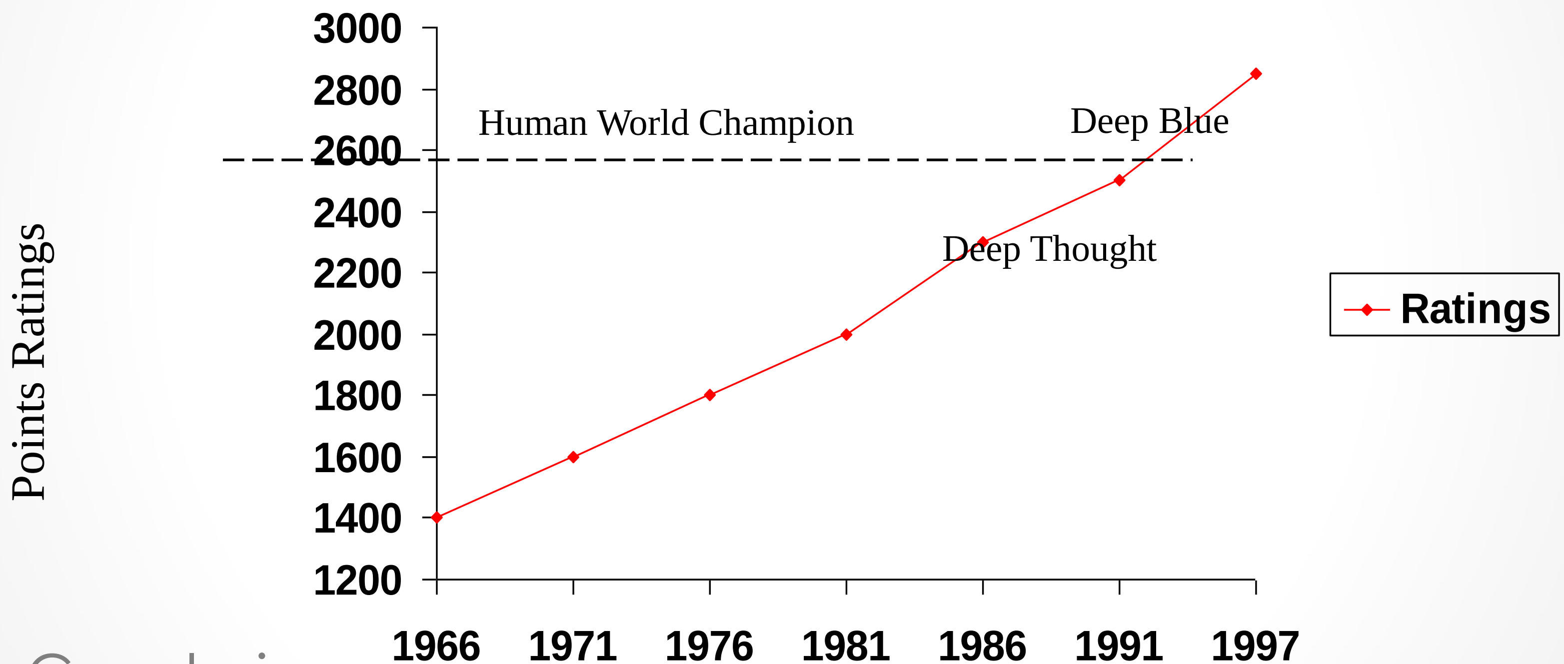


Newell and Simon Prediction

In 1997, Deep Blue beat Gary Kasparov.

Can Computers beat Humans at Chess?

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

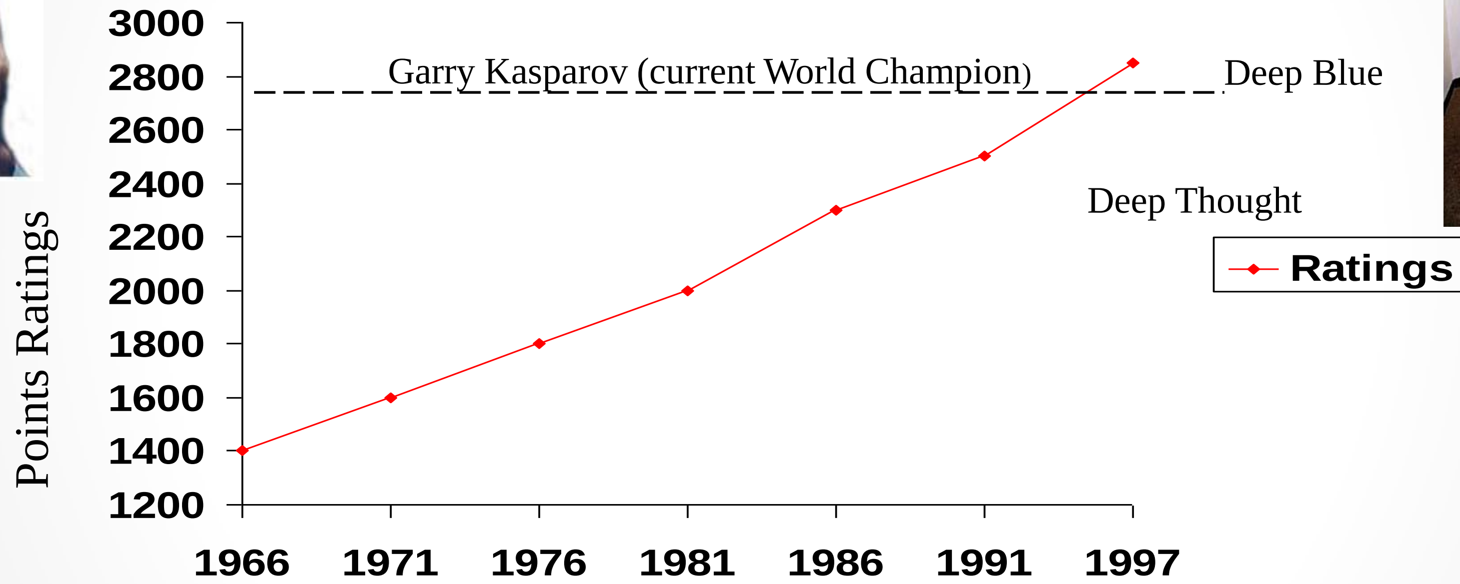


- Conclusion:
  - YES: today's computers can beat even the best human

•Deep Blue defeated the reigning world chess champion Garry Kasparov in 1997

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
  - YES, for individual words

Can Computers Recognize Speech?

- Speech Recognition:
  - mapping sounds from a microphone into a list of words
  - classic problem in AI, very difficult

- 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
      - e.g., hypothesize and test
      - 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 60-70% accurate

- Conclusion:
  - NO, normal speech is too complex to accurately recognize
  - YES, for restricted problems (small vocabulary, single speaker)

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

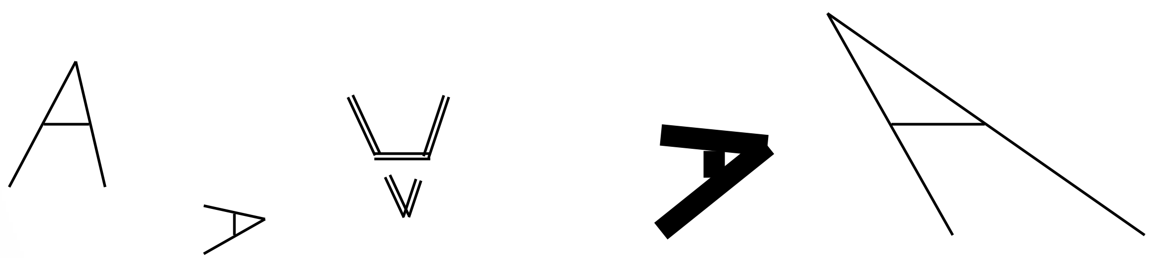
Darpa's Grand Challenge. Stanford's "Stanley" drove 150 without supervision in the Majove dessert

  - **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
    - 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 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.

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
- Credit Card Companies
  - automated fraud detection
- Computer Companies
  - automated diagnosis for help-desk applications
- Netflix:
  - movie recommendation
- Google:
  - Search Technology

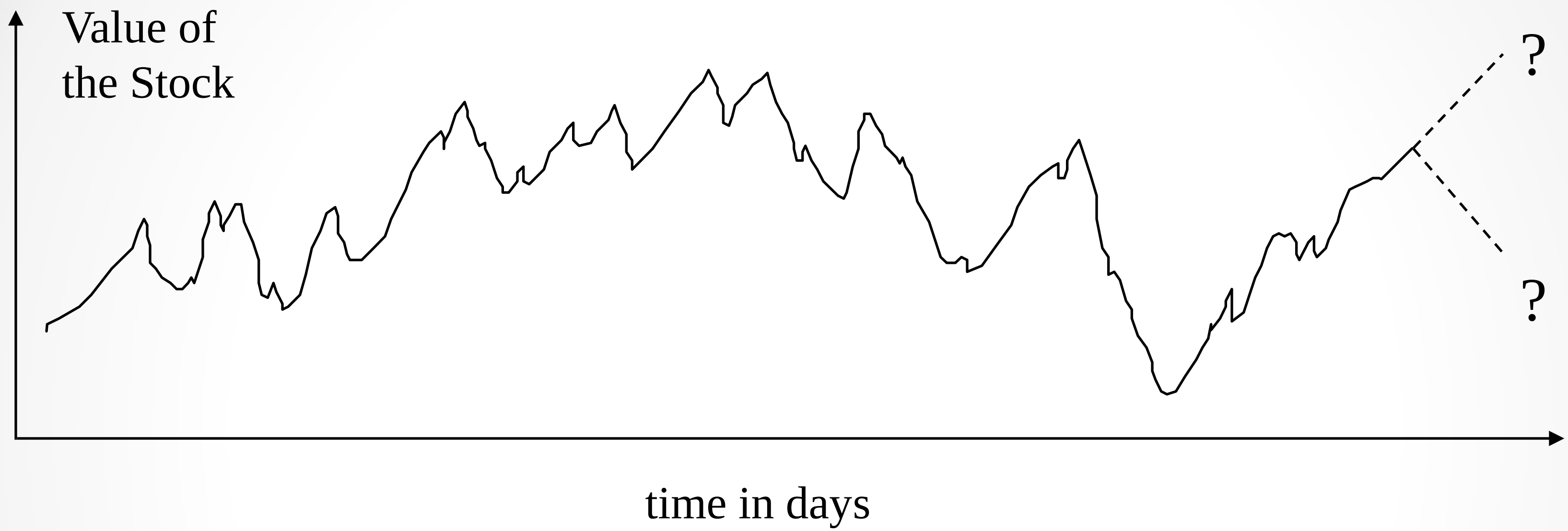
AI Applications: Consumer Marketing

- 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 a lot 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

The agenda of AI class:

1. Fuzzy logic
2. Prepositional logic – prolog – expert systems with inference algorithms
3. Rough set theory
4. Decision trees, kNN, Naive Bayes
5. Neural network