What is Intelligence?

- Here are some definitions:
  - *the ability to comprehend; to understand and profit from experience*
  - *a general mental capability that involves the ability to reason, plan, solve problems, think abstractly, comprehend ideas and language, and learn*
  - *is effectively perceiving, interpreting and responding to the environment*
- None of these tells us what intelligence is, so instead, maybe we can enumerate a list of elements that an intelligence must be able to perform:
  - perceive, reason and infer, solve problems, learn and adapt, apply common sense, apply analogy, recall, apply intuition, reach emotional states, achieve self-awareness
- Which of these are necessary for intelligence? Which are sufficient?
- Artificial Intelligence – should we define this in terms of human intelligence?
  - does AI have to really be intelligent?
  - what is the difference between being intelligent and demonstrating intelligent behavior?

AI Definitions

- The study of how to make programs/computers do things that people do better
- The study of how to make computers solve problems which require knowledge and intelligence
- The exciting new effort to make computers think … machines with minds
- The automation of activities that we associate with human thinking (e.g., decision-making, learning…)
- The art of creating machines that perform functions that require intelligence when performed by people
- The study of mental faculties through the use of computational models
- A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes
- The branch of computer science that is concerned with the automation of intelligent behavior

Thinking machines or machine intelligence

Studying cognitive science

Problem Solving and CS

So What Is AI?

- AI as a field of study
  - Computer Science
  - Cognitive Science
  - Psychology
  - Philosophy
  - Linguistics
  - Neuroscience
- AI is part science, part engineering
- AI often must study other domains in order to implement systems
  - e.g., medicine and medical practices for a medical diagnostic system, engineering and chemistry to monitor a chemical processing plant
- AI is a belief that the brain is a form of biological computer and that the mind is computational

Foundations of AI

- Philosophy
  - 450 BC, Socrates asked for algorithm to distinguish pious from non-pious individuals
  - Aristotle developed laws for reasoning
- Mathematics
  - 1847, Boole introduced formal language for making logical inference
- Economics
  - 1776, Smith views economies as consisting of agents maximizing their own well being (payoff)
- Neuroscience
  - 1861, Study how brains process information
- Psychology
  - 1879, Cognitive psychology initiated
- Linguistics
  - 1957, Skinner studied behaviorist approach to language learning

History of AI

- CS-based AI started with “Dartmouth Conference” in 1956
- Attendees
  - John McCarthy
    - LISP, application of logic to reasoning
  - Marvin Minsky
    - Popularized neural networks
    - Slots and frames
    - The Society of the Mind
  - Claude Shannon
    - Computer checkers
    - Information theory
    - Open-loop 5-ball juggling
  - Allen Newell and Herb Simon
    - General Problem Solver

1950s

- Computers were thought of as an electronic brains
- Term “Artificial Intelligence” coined by John McCarthy
  - John McCarthy also created Lisp in the late 1950s
- Alan Turing defines intelligence as passing the Imitation Game (Turing Test)
- AI research largely revolves around toy domains
  - Computers of the era didn’t have enough power or memory to solve useful problems
  - Problems being researched include
    - games (e.g., checkers)
    - primitive machine translation
    - blocks world (planning and natural language understanding within the toy domain)
    - early neural networks researched: the perceptron
    - automated theorem proving and mathematics problem solving

1960s

- AI attempts to move beyond toy domains
- Syntactic knowledge alone does not work, domain knowledge required
  - Early machine translation could translate English to Russian ("the spirit is willing but the flesh is weak" becomes "the vodka is good but the meat is spoiled")
- Earliest expert system created: Dendral
- Perceptron research comes to a grinding halt when it is proved that a perceptron cannot learn the XOR operator
- US sponsored research into AI targets specific areas – not including machine translation
- Weizenbaum creates Eliza to demonstrate the futility of AI

1970s

- AI researchers address real-world problems and solutions through expert (knowledge-based) systems
  - Medical diagnosis
  - Speech recognition
  - Planning
  - Design
- Uncertainty handling implemented
  - Fuzzy logic
  - Certainty factors
  - Bayesian probabilities
- AI begins to get noticed due to these successes
  - AI research increased
  - AI labs sprouting up everywhere
  - AI shells (tools) created
  - AI machines available for Lisp programming
- Criticism: AI systems are too brittle, AI systems take too much time and effort to create, AI systems do not learn

1980s: AI Winter

- Funding dries up leading to the AI Winter
  - Too many expectations were not met
  - Expert systems took too long to develop, too much money to invest, the results did not pay off
- Neural Networks to the rescue!
  - Expert systems took programming, and took dozens of man-years of efforts to develop, but if we could get the computer to learn how to solve the problem…
  - Multi-layered back-propagation networks got around the problems of perceptrons
  - Neural network research heavily funded because it promised to solve the problems that symbolic AI could not
- By 1990, funding for neural network research was slowly disappearing as well
  - Neural networks had their own problems and largely could not solve a majority of the AI problems being investigated
  - Panic! How can AI continue without funding?

1990s: ALife

- The dumbest smart thing you can do is staying alive
  - We start over – lets not create intelligence, lets just create "life" and slowly build towards intelligence
    - Alife is the lower bound of AI
  - Alife includes
    - evolutionary learning techniques (genetic algorithms)
    - artificial neural networks for additional forms of learning
    - perception and motor control
    - adaptive systems
    - modeling the environment
- Let's disguise AI as something new, maybe we'll get some funding that way!
  - Problems: genetic algorithms are useful in solving some optimization problems and some search-based problems, but not very useful for expert problems
  - perceptual problems are among the most difficult being solved, very slow progress

Today: The New (Old) AI

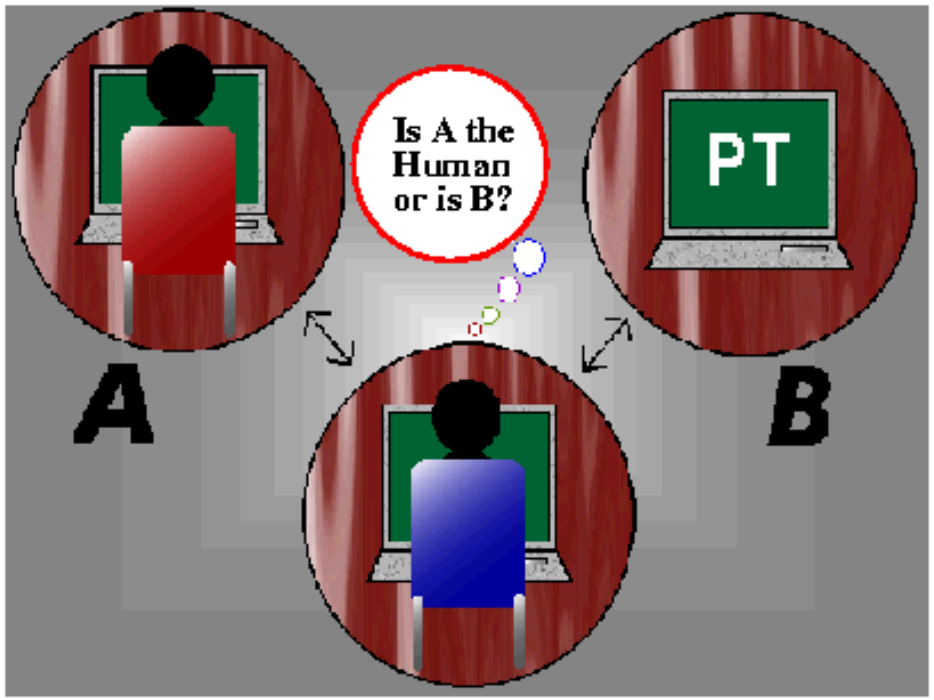
- Look around, who is doing AI research?
- By their own admission, AI researchers are not doing “AI”, they are doing
  - Intelligent agents, multi-agent systems/collaboration
  - Ontologies
  - Machine learning and data mining
  - Adaptive and perceptual systems
  - Robotics, path planning
  - Search engines, filtering, recommendation systems
- Areas of current research interest:
  - NLU/Information Retrieval, Speech Recognition
  - Planning/Design, Diagnosis/Interpretation
  - Sensor Interpretation, Perception, Visual Understanding
  - Robotics
- Approaches
  - Knowledge-based
  - Ontologies
  - Probabilistic (HMM, Bayesian Nets)
  - Neural Networks, Fuzzy Logic, Genetic Algorithms

AI Definition

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 bcttcr." (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)

Approach 1: Acting Humanly

- Turing test: ultimate test for acting humanly
  - Computer and human both interrogated by judge
  - Computer passes test if judge can't tell the difference



Approach 2: Thinking Humanly

- Requires knowledge of brain function
- What level of abstraction?
- How can we validate this
- This is the focus of Cognitive Science

Approach 3: Thinking Rationally

- Aristotle attempted this (laws of thought)
- What are correct arguments or thought processes?
- Provided foundation of much of AI
- Not all intelligent behavior controlled by logic

Approach 4: Acting Rationally

- Act to achieve goals, given set of beliefs
- Rational behavior is doing the “right thing”
  - Thing which expects to maximize goal achievement
- This is approach adopted by Russell & Norvig

Solving the Turing Test: Eliza

- Created by Joseph Weizenbaum
- This system would act like a Rogerian psychoanalyst by holding a dialog with a person
  - the dialog would be consist of the doctor (Eliza) asking questions, the human responding, and the doctor using the response to ask another question
- Weizenbaum wrote the program so that it would generate an English response/question based on a group of patterns
  - If the user sentence matched a pattern, this pattern would be used to generate the next sentence/question

Example Eliza Dialog

- H: Men are all alike
- E: In what way?
- H: They're always bugging us about something or another.
- E: Can you be more specific?
- H: Well, my boyfriend made me come here.
- E: Your boyfriend made you come here?
- H: He says I'm depressed much of the time.
- E: I am sorry to hear you are depressed.
- H: It's true. I am unhappy.
- E: Do you think coming here will help you not to be unhappy?
- H: I need some help, that much seems certain.
- E: What would it mean to you if you got some help?
- H: Perhaps I could learn to get along with my mother.
- E: Tell me more about your family

(?* ?x) hello (?* ?y) →
(How do you do. Please state your problem.)
(?* ?x) I want (?* ?y) →
(What would it mean if you got ?y)
(Why do you want ?y)
(Suppose you got ?y soon)
(?* ?x) if (?* ?y) →
(Do you really think its likely that ?y)
(Do you wish that ?y)
(What do you think about ?y) (Really-- if ?y)
(?* ?x) no (?* ?y) → (Why not?)
(You are being a bit negative)
(Are you saying "NO" just to be negative?)
(?* ?x) I was (?* ?y) → (Were you really?)
(Perhaps I already knew you were ?y)
(Why do you tell me you were ?y now?)
(?* ?x) I feel (?* ?y) → (Do you often feel ?y ?)
(?* ?x) I felt (?* ?y) →
(What other feelings do you have?)

Eliza Rules

Eliza also has a rule to swap ‘I’ and ‘my’ to ‘you’ and ‘your’

How effective is this test?

- Agent must:
  - Have command of language
  - Have wide range of knowledge
  - Demonstrate human traits (humor, emotion)
  - Be able to reason
  - Be able to learn
- Loebner prize competition is modern version of Turing Test
  - Example: Alice, Loebner prize winner for 2000 and 2001

Chinese Room Argument

Imagine you are sitting in a room with a library of rule books, a bunch of blank exercise books, and a lot of writing utensils. Your only contact with the external world is through two slots in the wall labeled ``input'' and ``output''. Occasionally, pieces of paper with Chinese characters come into your room through the ``input'' slot. Each time a piece of paper comes in through the input slot your task is to find the section in the rule books that matches the pattern of Chinese characters on the piece of paper. The rule book will tell you which pattern of characters to inscribe the appropriate pattern on a blank piece of paper. Once you have inscribed the appropriate pattern according to the rule book your task is simply to push it out the output slot.

By the way, you don't understand Chinese, nor are you aware that the symbols that you are manipulating are Chinese symbols.

In fact, the Chinese characters which you have been receiving as input have been questions about a story and the output you have been producing has been the appropriate, perhaps even "insightful," responses to the questions asked. Indeed, to the outside questioners your output has been so good that they are convinced that whoever (or whatever) has been producing the responses to their queries must be a native speaker of, or at least extremely fluent in, Chinese.

Searle's Question

- You were able to solve the problem of communicating with the person/user and thus you/the room passes the Turing Test
- But did you understand the Chinese messages being communicated?
  - since you do not speak Chinese, you did not understand the symbols in the question, the answer, or the storage
  - can we say that you actually *used* any intelligence?
- By analogy, since you did not understand the symbols that you interacted with, neither does the computer understand the symbols that it interacts with (input, output, program code, data)
- Searle concludes that the computer is not intelligent, it has no "semantics," but instead is merely a symbol manipulating device
  - the computer operates solely on syntax, not semantics
- He defines to categories of AI:
  - strong AI – the pursuit of machine intelligence
  - weak AI – the pursuit of machines solving problems in an intelligent way

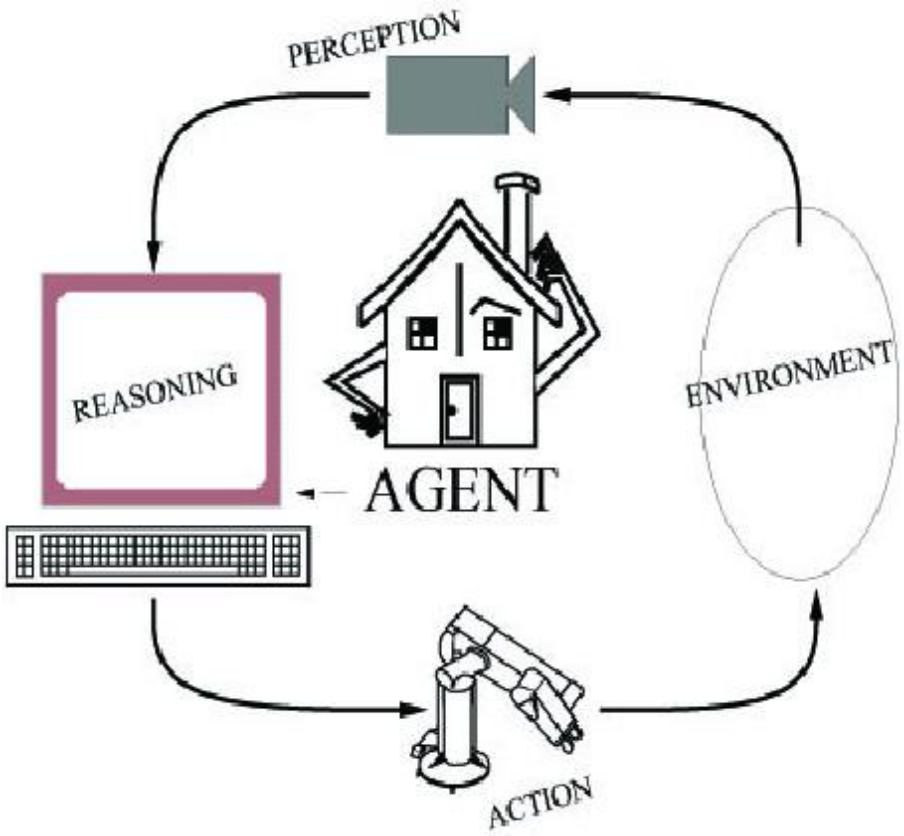
But Computers Solve Problems

- We can clearly see that computers solve problems in a seemingly intelligent way
  - Where is the intelligence coming from?
- There are numerous responses to Searle's argument
  - The System's Response:
    - the hardware by itself is not intelligent, but a combination of the hardware, software and storage is intelligent
    - in a similar vein, we might say that a human brain that has had no opportunity to learn anything cannot be intelligent, it is just the hardware
  - The Robot Response:
    - a computer is void of senses and therefore symbols are meaningless to it, but a robot with sensors can tie its symbols to its senses and thus understand symbols
  - The Brain Simulator Response:
    - if we program a computer to mimic the brain (e.g., with a neural network) then the computer will have the same ability to understand as a human brain

So What Does AI Do?

- Most AI research has fallen into one of two categories
  - Select a specific problem to solve
    - study the problem (perhaps how humans solve it)
    - come up with the proper representation for any knowledge needed to solve the problem
    - acquire and codify that knowledge
    - build a problem solving system
  - Select a category of problem or cognitive activity (e.g., learning, natural language understanding)
    - theorize a way to solve the given problem
    - build systems based on the model behind your theory as experiments
    - modify as needed
- Both approaches require
  - one or more representational forms for the knowledge
  - some way to select proper knowledge, that is, search

Components of an AI System



An agent perceives its environment through sensors and acts on the environment through actuators.

Human: sensors are eyes, ears, actuators (effectors) are hands, legs, mouth.

Robot: sensors are cameras, sonar, lasers, ladar, bump, effectors are grippers, manipulators, motors

The agent's behavior is described by its function that maps percept to action.