CS 561: Artificial Intelligence

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Lectures: MW 5:00-6:20pm, OHE 122 / DEN
Office hours: By appointment
Class page: http://www-rcf.usc.edu/~macskass/CS561-Spring2010/

This class will use http://www.uscden.net/ and class webpage
- Up to date information
- Lecture notes
- Relevant dates, links, etc.

Course material:
[AIMA] Artificial Intelligence: A Modern Approach,
by Stuart Russell and Peter Norvig. (2nd ed)

CS 561: Artificial Intelligence

Course overview: foundations of symbolic intelligent systems. Agents, search, problem solving, logic, representation, reasoning, symbolic programming, and robotics.

Prerequisites: programming principles, discrete mathematics for computing, software design and software engineering concepts. Good knowledge of C++ and STL required for programming assignments.

Grading:
20% for homeworks (4 homeworks, 5% each)
20% for programming projects (2 projects, 10% each)
30% for midterms (2 midterms, 15% each) +
30% for final (cumulative)

1 day late = 25% reduction in score
2 days late = 50% reduction in score

NOTE: You have 1 week from getting a homework/project/midterm to get it reviewed if you feel it was wrongly graded

Practical issues

- **Class mailing list:**
  will be setup on the backboard system

- **Homeworks:** See class web page on blackboard
  - Jan 25 – HW1 out
  - Feb 10 – HW1 due, HW2 out
  - Feb 22 – HW2 due
  - Mar 8 – HW3 out
  - Mar 22 – HW3 due, HW4 out
  - Apr 5 – HW4 due

- **Projects:** See class web page on blackboard
  - Feb 1 - Project 1 out
  - Mar 8 - Project 1 due, Project 2 out
  - Apr 19 - Project 2 due

- **Exams:**
  - Mar 1 – midterm 1 (in class)
  - Apr 12 – midterm 2 (in class)
  - May 5 – final (room TBA)

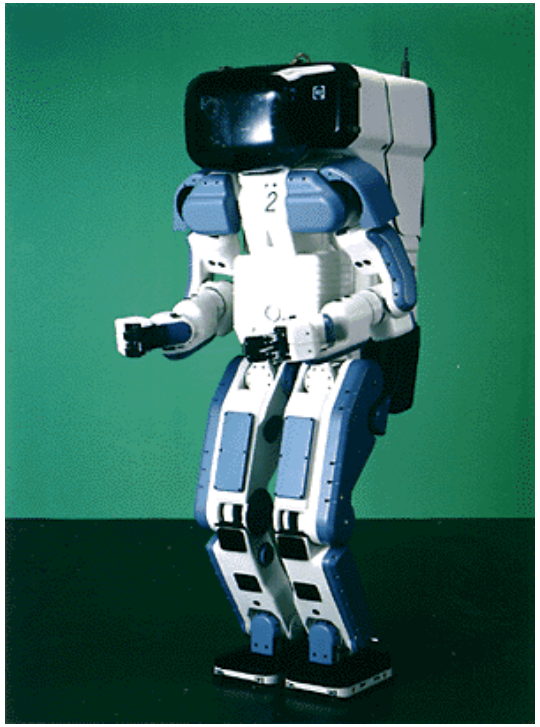
Academic Integrity

- Familiarize yourself with the USC Academic Integrity guidelines.
- Violations of the Student Conduct Code will be filed with the Office of Student Judicial Affairs, and appropriate sanctions will be given.
- Homework assignments are to be solved **individually.**
- You are welcome to discuss class material in review groups, but do not discuss how to solve the homeworks.
- **Exams are open-book.**

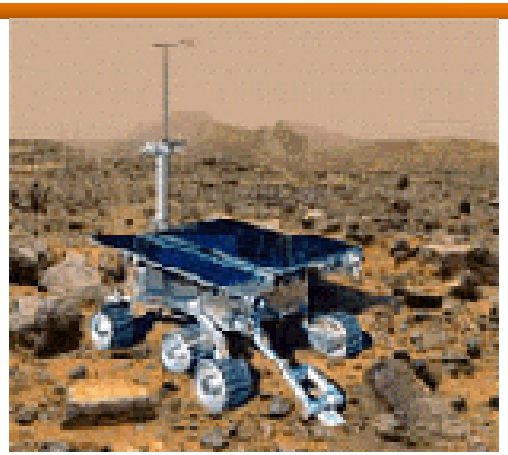
Today: Introduction

- AIMA Chapter 1

Why study AI?



Labor



Science

Google

YAHOO!

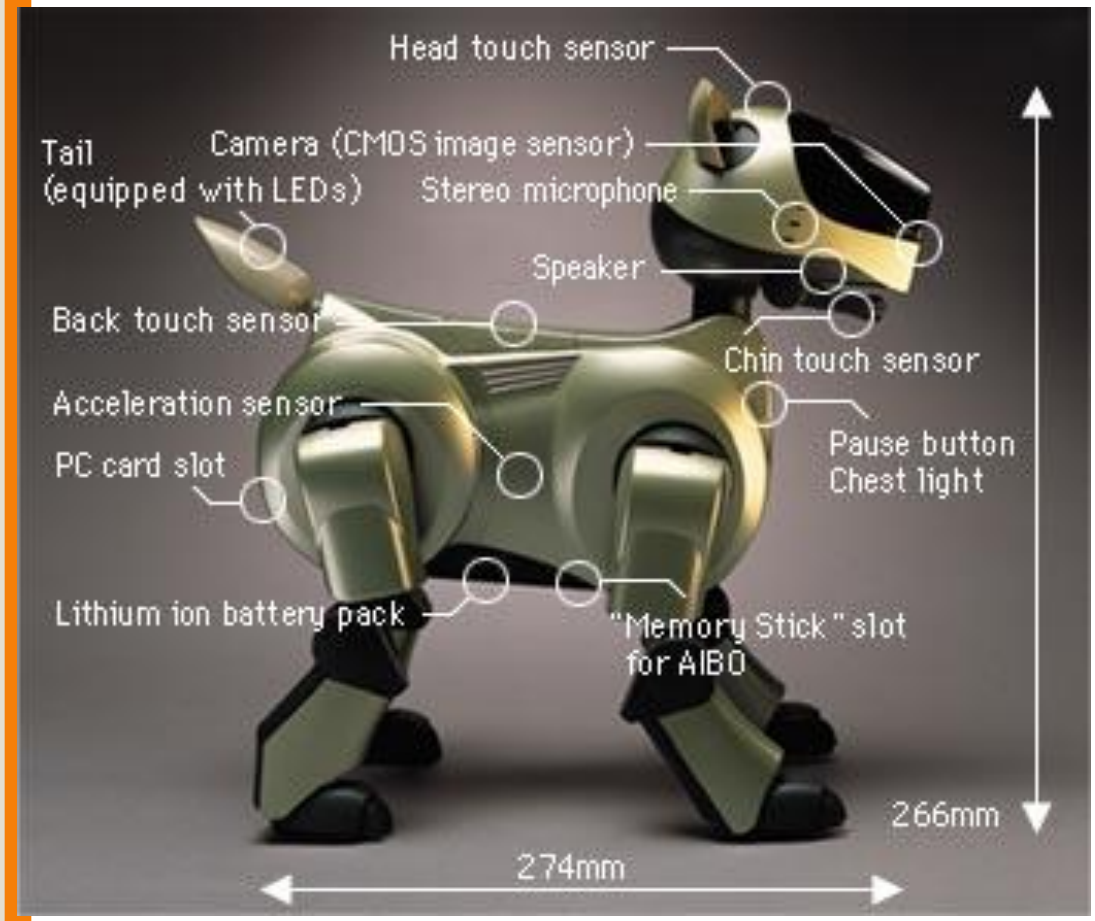
Search engines

Medicine/
Diagnosis

Appliances

What else?

Sony AIBO



http://www.aibo.com

Sony QRIO

Natural Language Question Answering

http://aimovie.warnerbros.com

http://www.ai.mit.edu/projects/infolab/

DARPA grand challenge

- Race of autonomous vehicles across california desert
- Vehicles are given a route as series of GPS waypoints
- But they must intelligently avoid obstacles and stay on the road
- About 130 miles of dirt roads, off-road, normal roads, bridges, tunnels, etc
- Must complete in less than 10 hours

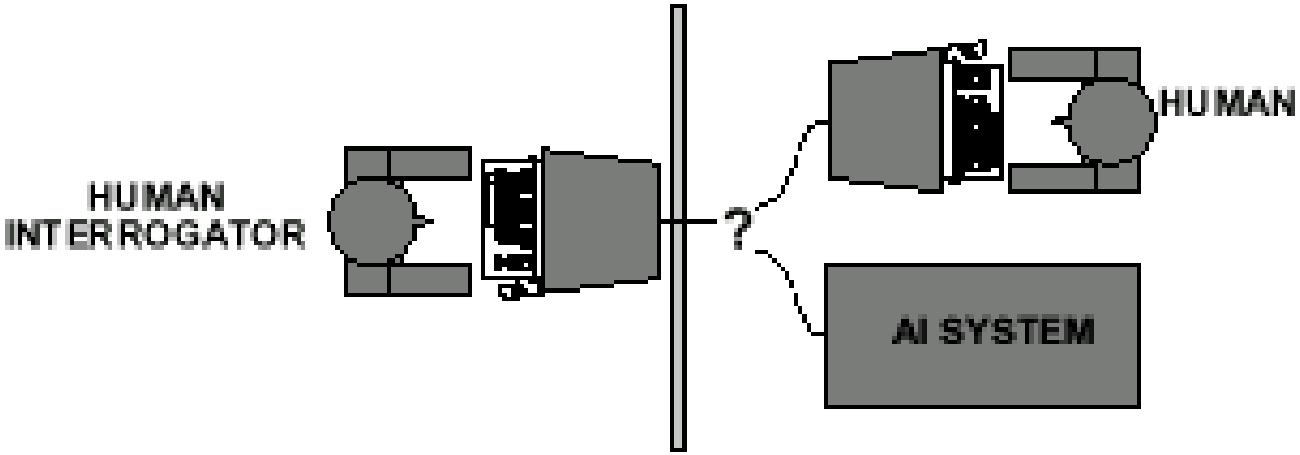
What is AI?

The exciting new effort to make computers thinks … machine with minds, in the full and literal sense" (Haugeland 1985)	"The study of mental faculties through the use of computational models" (Charniak et al. 1985)
"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990)	A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkol, 1990)

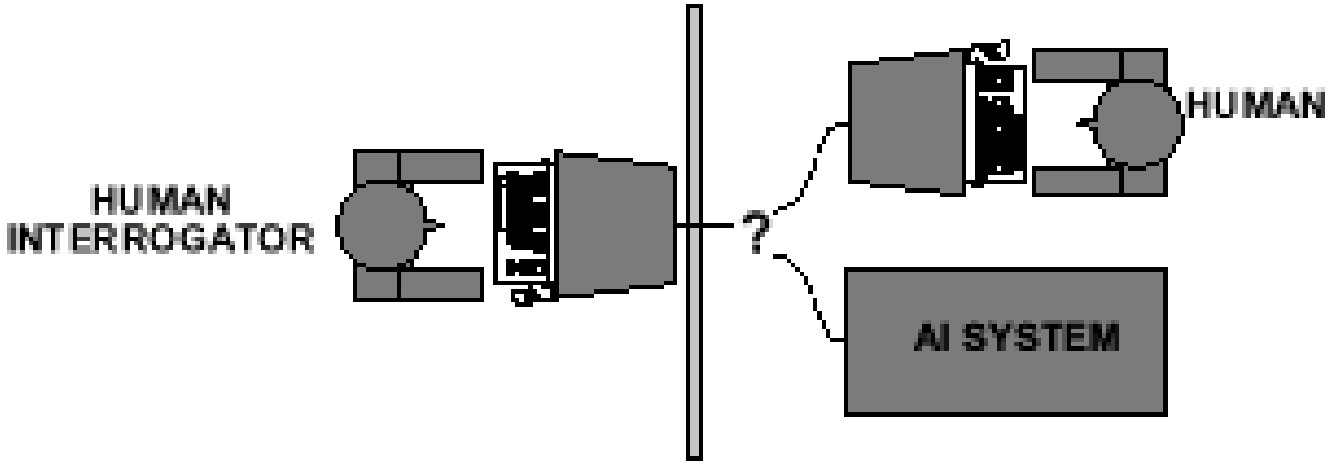
Systems that think like humans	Systems that think rationally
Systems that act like humans	Systems that act rationally

Acting Humanly: The Turing Test

- Alan Turing's 1950 article Computing Machinery and Intelligence discussed conditions for considering a machine to be intelligent
  - "Can machines think?" → "Can machines behave intelligently?"
  - The Turing test (The Imitation Game): Operational definition of intelligence.



Acting Humanly: The Turing Test



- Computer needs to possess: Natural language processing, Knowledge representation, Automated reasoning, and Machine learning

- Are there any problems/limitations to the Turing Test?

What tasks require AI?

Acting Humanly: The Full Turing Test

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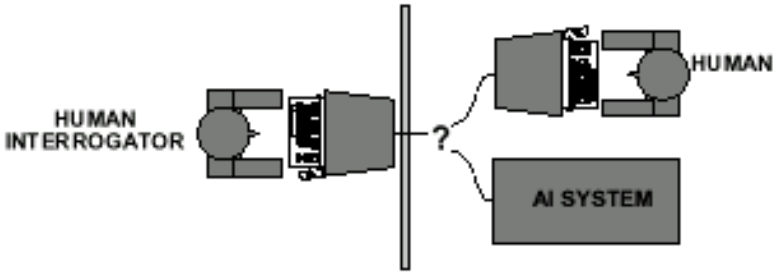
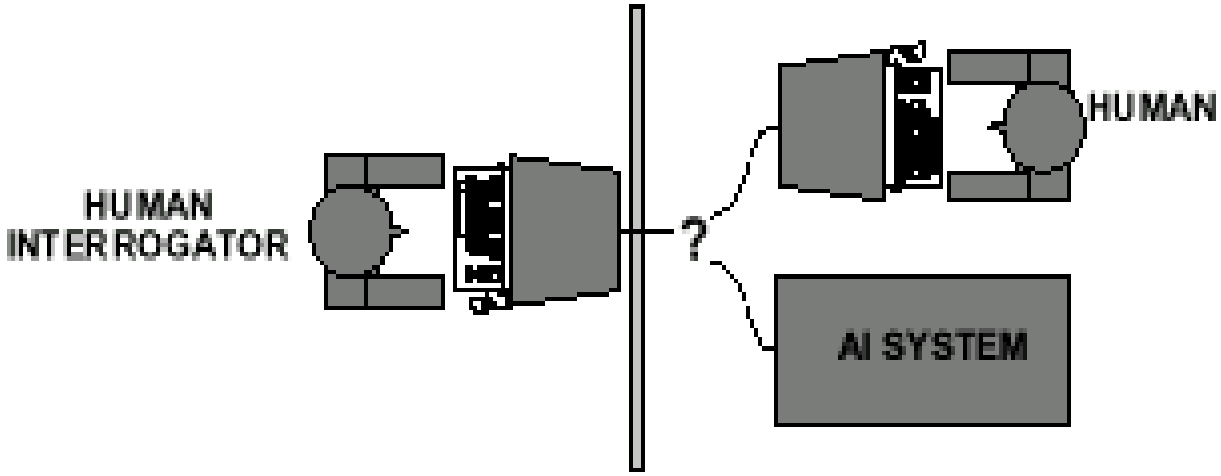


- Computer needs to posses:Natural language processing, Knowledge representation, Automated reasoning, and Machine learning

- Problem: 1) Turing test is not reproducible, constructive, and amenable to mathematic analysis. 2) What about physical interaction with interrogator and environment?
- Total Turing Test: Requires physical interaction and needs perception and actuation.

Acting Humanly: The Full Turing Test



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Acting Humanly: The Full Turing Test

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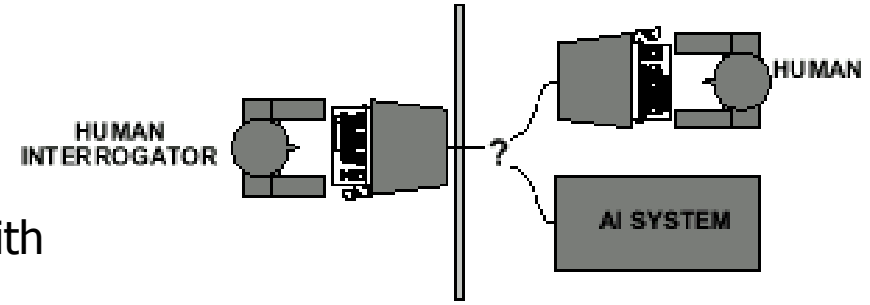
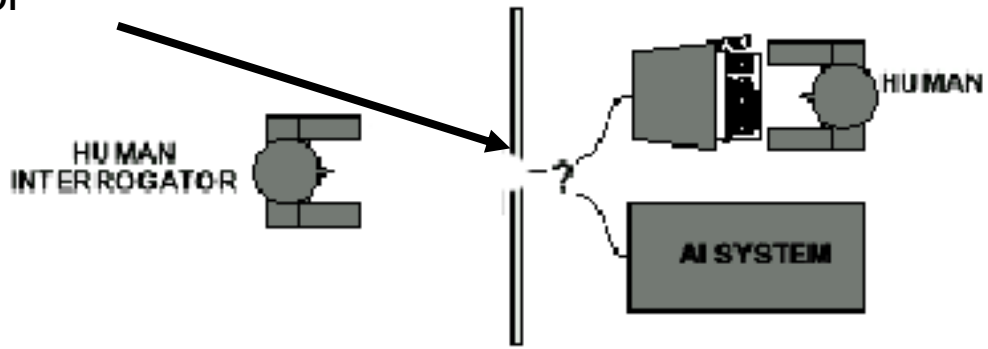


Trap door



What would a computer need to pass the Turing test?

- Natural language processing: to communicate with examiner.
- Knowledge representation: to store and retrieve information provided before or during interrogation.
- 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.

What would a computer need to pass the Turing test?

- Vision (for Total Turing test): to recognize the examiner's actions and various objects presented by the examiner.
- Motor control (total test): to act upon objects as requested.
- Other senses (total test): such as audition, smell, touch, etc.

Thinking Humanly: Cognitive Science

- 1960 "Cognitive Revolution": information-processing psychology replaced behaviorism
- Cognitive science brings together theories and experimental evidence to model internal activities of the brain
  - What level of abstraction? "Knowledge" or "Circuits"?
  - How to validate models?
    - Predicting and testing behavior of human subjects (top-down)
    - Direct identification from neurological data (bottom-up)
    - Building computer/machine simulated models and reproduce results (simulation)

Thinking Rationally: Laws of Thought

- Aristotle (~ 450 B.C.) attempted to codify "right thinking"
  What are correct arguments/thought processes?

- E.g., "Socrates is a man, all men are mortal; therefore Socrates is mortal"

- Several Greek schools developed various forms of logic:
  notation plus rules of derivation for thoughts.

Thinking Rationally: Laws of Thought

- Problems:
  1) Uncertainty: Not all facts are certain (e.g., the flight might be delayed).

  2) Resource limitations:
     - Not enough time to compute/process
     - Insufficient memory/disk/etc
     - Etc.

Acting Rationally: The Rational Agent

- Rational behavior: Doing the right thing!
- The right thing: That which is expected to maximize the expected return
- Provides the most general view of AI because it includes:
  - Correct inference ("Laws of thought")
  - Uncertainty handling
  - Resource limitation considerations (e.g., reflex vs. deliberation)
  - Cognitive skills (NLP, AR, knowledge representation, ML, etc.)
- Advantages:
  1) More general
  2) Its goal of rationality is well defined

How to achieve AI?

- How is AI research done?
- AI research has both theoretical and experimental sides. The experimental side has both basic and applied aspects.
- There are two main lines of research:
  - One is biological, based on the idea that since humans are intelligent, AI should study humans and imitate their psychology or physiology.
  - The other is phenomenal, based on studying and formalizing common sense facts about the world and the problems that the world presents to the achievement of goals.
- The two approaches interact to some extent, and both should eventually succeed. It is a race, but both racers seem to be walking. [**John McCarthy**]

Branches of AI

- **Logical AI**
- **Search**
- **Natural language processing**
- **pattern recognition**
- **Knowledge representation**
- **Inference** From some facts, others can be inferred.
- **Automated reasoning**
- **Learning from experience**
- **Planning** To generate a strategy for achieving some goal
- **Epistemology** Study of the kinds of knowledge that are required for solving problems in the world.
- **Ontology** Study of the kinds of things that exist. In AI, the programs and sentences deal with various kinds of objects, and we study what these kinds are and what their basic properties are.
- **Genetic programming**
- **Emotions???**
- …

AI Prehistory

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
Psychology	- adaptation
	- phenomena of perception and motor control
	- experimental techniques (psychophysics, etc.)
Economics	- formal theory of rational decisions
Linguistics	- knowledge representation
	- grammar
Neuroscience	- plastic physical substrate for mental activity
Control theory	- homeostatic systems, stability
	- simple optimal agent designs

AI History

- 1943 McCulloch & Pitts: Boolean circuit model of brain
- 1950 Turing's "Computing Machinery and Intelligence"
- 1952-69 Look, Ma, no hands!
- 1950s Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
- 1956 Dartmouth meeting: "Articial Intelligence" adopted
- 1965 Robinson's complete algorithm for logical reasoning
- 1966-74 AI discovers computational complexity, Neural network research almost disappears
- 1969-79 Early development of knowledge-based systems
- 1980-88 Expert systems industry booms
- 1988-93 Expert systems industry busts: "AI Winter"
- 1985-95 Neural networks return to popularity
- 1988- Resurgence of probability; general increase in technical depth; "Nouvelle AI": ALife, GAs, soft computing
- 1995- Agents, agents, everywhere …
- 2003- Human-level AI back on the agenda

AI State of the art

- Have the following been achieved by AI?
  - World-class chess playing
  - Playing table tennis
  - Cross-country driving
  - Solving mathematical problems
  - Discover and prove mathematical theories
  - Engage in a meaningful conversation
  - Understand spoken language
  - Observe and understand human emotions
  - Express emotions
  - …

AI State of the art

Which of the following can be done at present?

- Play a decent game of table tennis
- Drive safely along a curving mountain road
- Drive safely along Telegraph Avenue
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at Berkeley Bowl
- Play a decent game of bridge
- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology
- Write an intentionally funny story
- Give competent legal advice in a specialized area of law
- Translate spoken English into spoken Swedish in real time
- Converse successfully with another person for an hour
- Perform a complex surgical operation
- Unload any dishwasher and put everything away

AI State of the art

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Unintentionally funny stories

- One day Joe Bear was hungry. He asked his friend Irving Bird where some honey was. Irving told him there was a beehive in the oak tree. Joe threatened to hit Irving if he didn't tell him where some honey was. The End.

- Henry Squirrel was thirsty. He walked over to the river bank where his good friend Bill Bird was sitting. Henry slipped and fell in the river. Gravity drowned. The End.

- Once upon a time there was a dishonest fox and a vain crow. One day the crow was sitting in his tree, holding a piece of cheese in his mouth. He noticed that he was holding the piece of cheese. He became hungry, and swallowed the cheese. The fox walked over to the crow. The End.

Unintentionally funny stories

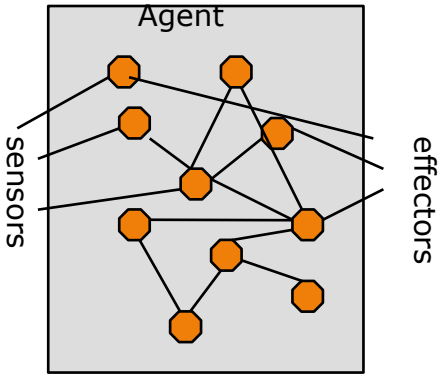
- Joe Bear was hungry. He asked Irving Bird where some honey was. Irving refused to tell him, so Joe offered to bring him a worm if he'd tell him where some honey was. Irving agreed. But Joe didn't know where any worms were, so he asked Irving, who refused to say. So Joe offered to bring him a worm if he'd tell him where a worm was. Irving agreed. But Joe didn't know where any worms were, so he asked Irving, who refused to say. So Joe offered to bring him a worm if he'd tell him where a worm was …

Course Overview

General Introduction

- **01-Introduction.** [AIMA Ch 1] Course Schedule. Homeworks, exams and grading. Course material, TAs and office hours. Why study AI? What is AI? The Turing test. Rationality. Branches of AI. Research disciplines connected to and at the foundation of AI. Brief history of AI. Challenges for the future. Overview of class syllabus.

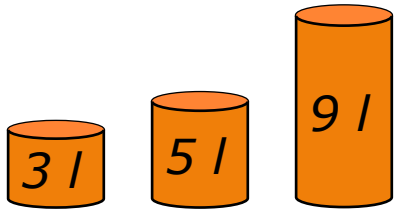
- **02-Intelligent Agents.** [AIMA Ch 2] What is an intelligent agent? Examples. Doing the right thing (rational action). Performance measure. Autonomy. Environment and agent design. Structure of agents. Agent types. Reflex agents. Reactive agents. Reflex agents with state. Goal-based agents. Utility-based agents. Mobile agents. Information agents.



Course Overview (cont.)

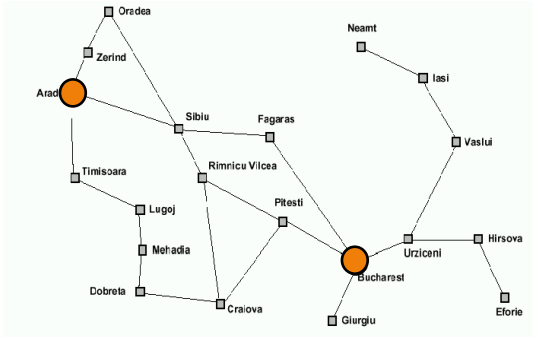
How can we solve complex problems?

- **03/04-Problem solving and search.** [AIMA Ch 3] Example: measuring problem. Types of problems. Example problems. Basic idea. Complexity. Combinatorial explosion and NP completeness. Polynomial hierarchy, Depth-first, Breadth-first, Iterative deepening.



Using these 3 buckets, measure 7 liters of water.

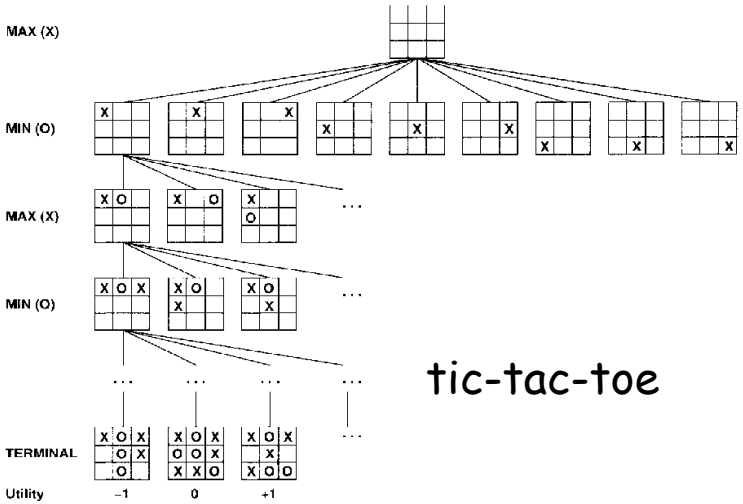
- **05/06-Heuristic search.** [AIMA Ch 4] Best-first. A* search. Heuristics. Hill climbing. Problem of local extrema. Simulated annealing.



Traveling salesperson problem

Course Overview (cont.)

- **07-Game playing.**
  [AIMA Ch 6] Minimax alg.
  Resource limitations.
  Aplha-beta pruning.
  Elements of chance and
  non-deterministic games.



tic-tac-toe

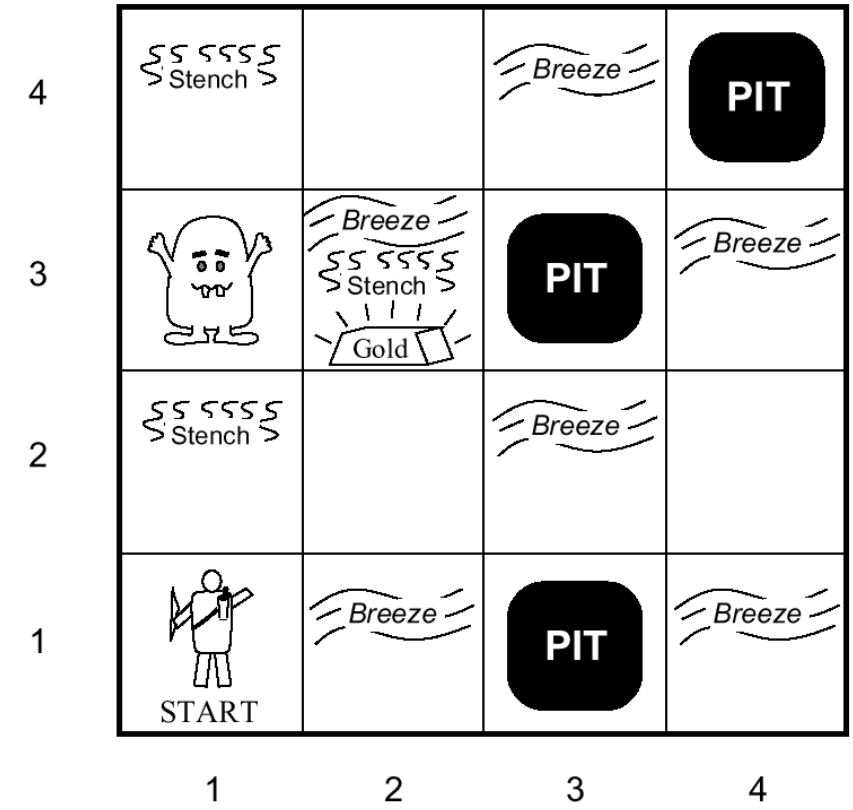
- **08-Constraint Satisfaction**
  [AIMA Ch 5]

Course Overview (cont.)

Towards intelligent agents

- **09-Agents that reason logically 1.** [AIMA Ch 7] Knowledge-based agents. Logic and representation. Propositional (boolean) logic.

- **10-Agents that reason logically 2.** [AIMA Ch 7] Inference in propositional logic. Syntax. Semantics. Examples.



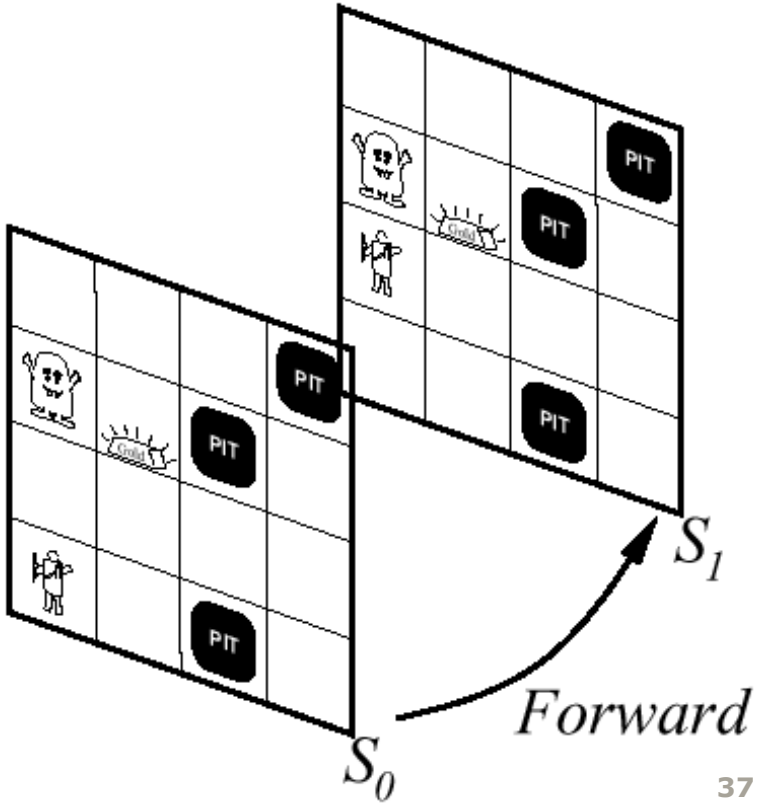
wumpus world

Course Overview (cont.)

Building knowledge-based agents: 1st Order Logic

- **11-First-order logic 1.** [AIMA Ch 8] Syntax. Semantics. Atomic sentences. Complex sentences. Quantifiers. Examples. FOL knowledge base. Situation calculus.

- **12-First-order logic 2.** [AIMA Ch 8] Describing actions. Planning. Action sequences.



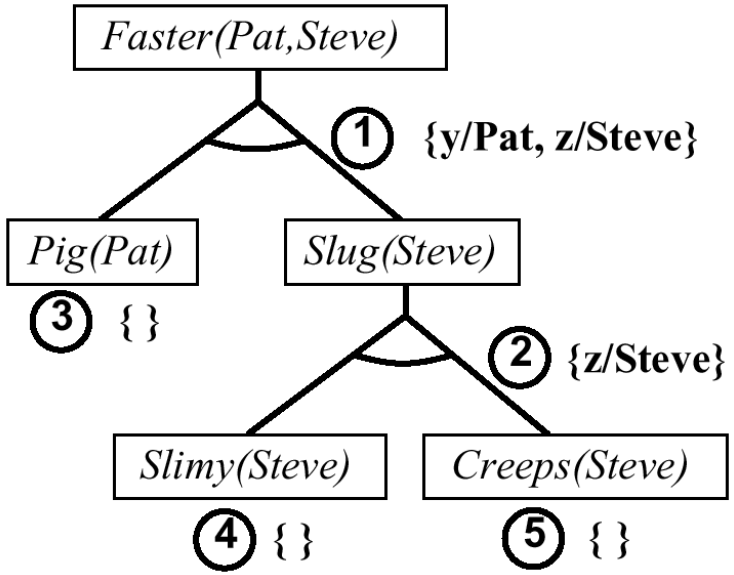
Course Overview (cont.)

- **13 – Midterm 1**

Course Overview (cont.)

Reasoning Logically

- **14/15-Inference in first-order logic.** [AIMA Ch 9] Proofs. Unification. Generalized modus ponens. Forward and backward chaining.



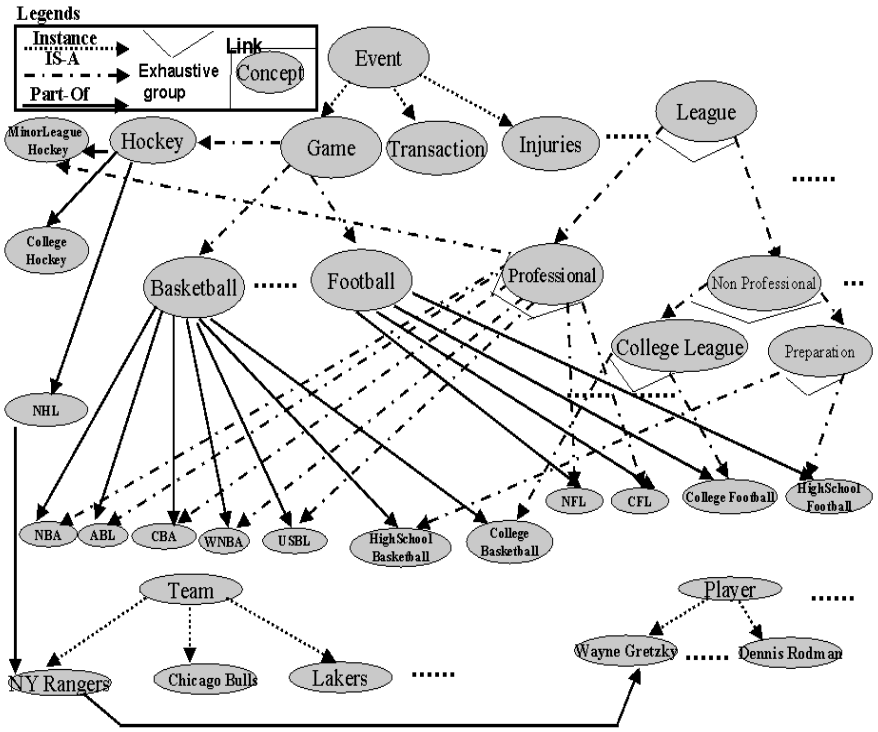
Example of backward chaining

Course Overview (cont.)

Representing and Organizing Knowledge

- **15/16-Building a knowledge base.** [AIMA Ch 10] Knowledge bases. Vocabulary and rules. Ontologies. Organizing knowledge.

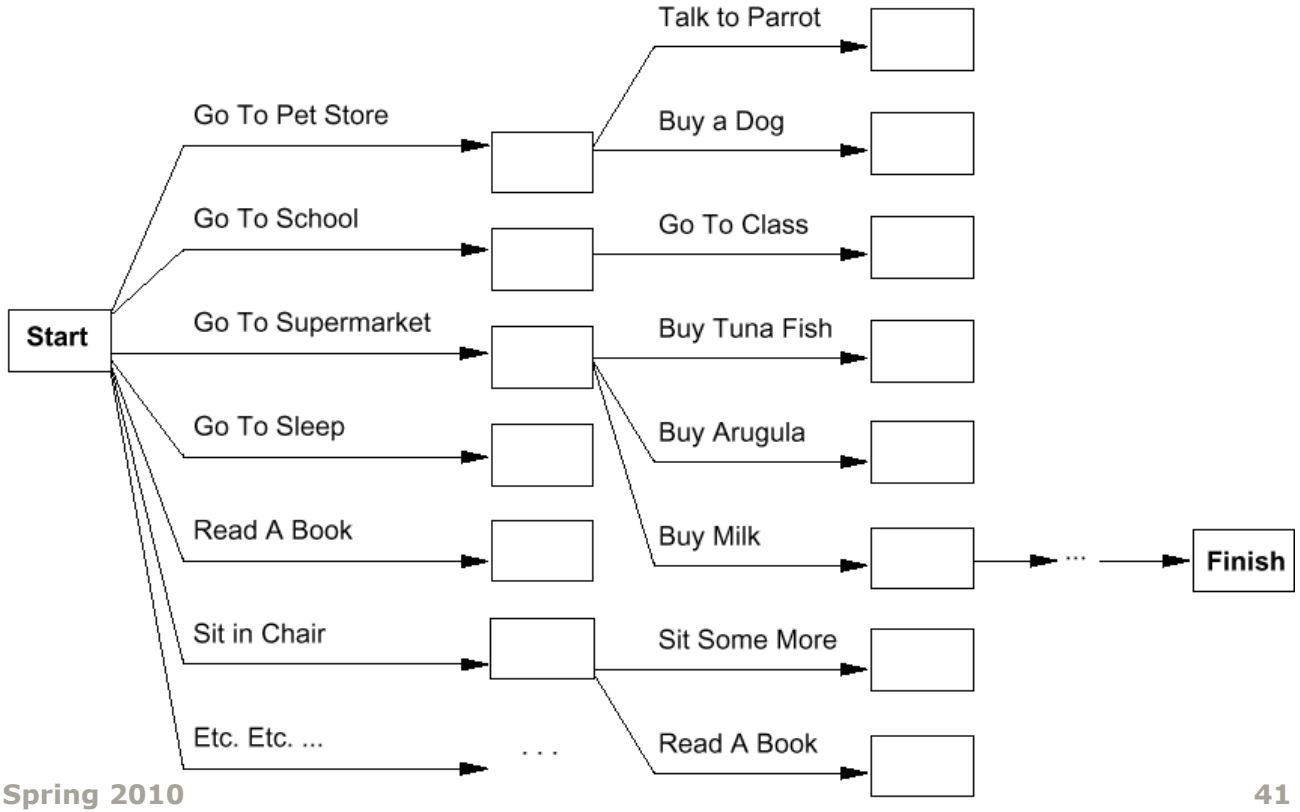
An ontology for the sports domain



Course Overview (cont.)

Systems that can Plan Future Behavior

- **17-Planning.** [AIMA Ch 11] Definition and goals. Basic representations for planning. Situation space and plan space. Examples.



Course Overview (cont.)

Expert Systems

- **18-Introduction to CLIPS.** [handout]
  Overview of modern rule-based expert systems. Introduction to CLIPS (C Language Integrated Production System). Rules. Wildcards. Pattern matching. Pattern network. Join network.

```
CLIPS> (clear)
CLIPS> (assert (animal-is duck))
<Fact-0>
CLIPS> (assert (animal-sound quack))
<Fact-1>
CLIPS> (assert (The duck says "Quack."))
<Fact-2>
CLIPS> (facts)
f-0     (animal-is duck)
f-1     (animal-sound quack)
f-2     (The duck says "Quack.")
For a total of 3 facts.
CLIPS>
```

CLIPS expert system shell

Course Overview (cont.)

- **19-Uncertainty** [AIMA Ch 13]

  Uncertainty, Basic Probability Theory, Syntax and Semantics for handling uncertainty, how to do inference in the presence of uncertainty, handling independence and Bayes' rule

Course Overview (cont.)

- **20/21-Probabilistic Reasoning** [AIMA Ch 14]
  Bayes nets and semantics, graphical models, semantics, Exact inference in Bayes nets, by enumeration, by variable elimination, approximate inference by simulation and Markov chain Monte Carlo

- **21/22-Probabilistic Reasoning over time** [AIMA Ch 15]

Course Overview (cont.)

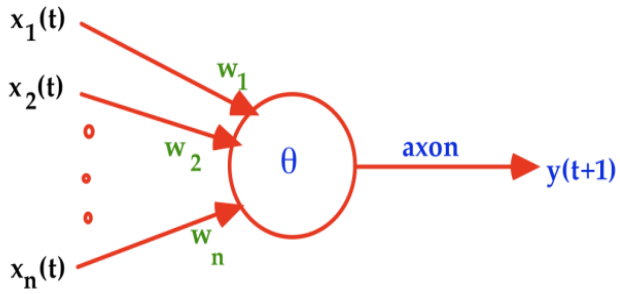
- **23 – Midterm 2**

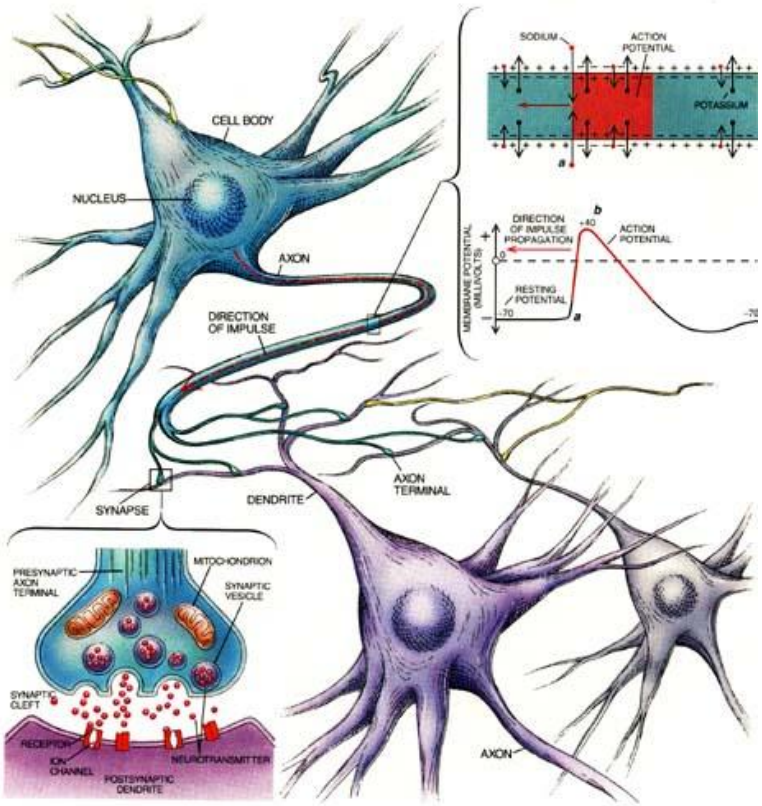
Course Overview (cont.)

- **24-Learning from Observations** [AIMA Ch 18]
  Learning agents, inductive learning, decision trees, measuring learning performance

Course Overview (cont.)

- **25/26-Statistical Learning** [AIMA Ch 20]
  Bayes learning, maximum likelihood estimation, Bayes net learning, Introduction to perceptrons, Hopfield networks, self-organizing feature maps. How to size a network? What can neural networks achieve?





Course Overview (cont.)

- **27-Communication and Language** [AIMA Ch 22]
  Communication, Language, Grammar, Syntactic Analysis

Course Overview (cont.)

- **28-Review**