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:
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?

- Search engines
- Science
- Medicine/Diagnosis
- Labor
- 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 a 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)

<table>
<thead>
<tr>
<th>Systems that think like humans</th>
<th>Systems that think rationally</th>
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<tr>
<td>Systems that act like humans</td>
<td>Systems that act rationally</td>
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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?
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.

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

- **Problem:**
  1) Turing test is not reproducible, constructive, and amenable to mathematic analysis.
  2) What about physical interaction with interrogator and environment?
Acting Humanly: The Full Turing Test

Problem:
1) Turing test is not reproducible, constructive, and amenable to mathematic analysis.
2) What about physical interaction with interrogator and environment?
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: "Artificial 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
  - ...

CS561 Lecture 1 - Macskassy - Spring 2010
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
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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.
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 ...
General Introduction


How can we solve complex problems?


Using these 3 buckets, measure 7 liters of water.

Traveling salesperson problem
• **07-Game playing.**
  Resource limitations.
  Aplha-beta pruning.
  Elements of chance and non-deterministic games.

• **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]
Building knowledge-based agents: 1st Order Logic


Course Overview (cont.)

- 13 – Midterm 1
Reasoning Logically


Example of backward chaining:

```
1. \{y/Pat, z/Steve\}
   
2. \{z/Steve\}
   
3. \{}
   
4. \{}
   
5. \{}
```

Diagram:

- `Faster(Pat,Steve)`
- `Pig(Pat)`
- `Slug(Steve)`
- `Slimy(Steve)`
- `Creeps(Steve)`
Representing and Organizing Knowledge

- **15/16-Building a knowledge base.** [AIMA Ch 10]

An ontology for the sports domain
Systems that can Plan Future Behavior

Expert Systems

18-Introduction to CLIPS. [handout]

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>
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
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