Class agenda:
- Final project / Midterm
- Readings
- AI, Agents, Artificial Life
- Group activity (if time!)

Readings


Big Questions

Can machines think?
And if so, how?
And if not, why not?
And what does this say about human beings?
And what does this say about the mind?

What is AI?
What is AI?

There are no crisp definitions.
Here's one from John McCarthy, (He coined the phrase AI in 1956) - see http://www.formal.Stanford.EDU/jmc/whatisai/)

Q. What is artificial intelligence?
A. 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.

Q. Yes, but what is intelligence?
A. 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.

Other Definitions

AI is a collection of hard problems which can be solved by humans and other living things, but for which we don't have good algorithmic solutions.
E.g. understanding spoken natural language, medical diagnosis, circuit design, etc.

AI Problem + Sound theory = Engineering problem

Some problems used to be thought of as AI but are now considered not AI
E.g. compiling Fortran in 1955, symbolic mathematics in 1965

What's easy and what's hard?

It's been easier to mechanize many of the high level tasks we usually associate with "intelligence" in people:
E.g. Symbolic integration, proving theorems, playing chess, medical diagnosis etc.

It's been very hard to mechanize tasks that lots of animals can do:
Walking around without running into things
Catching prey and avoiding predators
Interpreting complex sensory information (e.g., visual, aural, ...)
Modeling the internal states of other animals from their behavior
Working as a team (e.g. with pack animals)

Is there a fundamental difference between the two categories?

Foundations of AI

Mathematics  Computer Science & Engineering  Philosophy
Economics  Biology
Psychology  Cognitive Science
Linguistics
Why AI?

Engineering:
To get machines to do a wider variety of useful things
E.g. understand spoken natural language, recognize individual people in visual scenes, find the best travel plan for a vacation etc.

Cognitive Science:
As a way to understand how natural minds and mental phenomena work
E.g. visual perception, memory, learning, language etc.

Philosophy:
As a way to explore some basic and interesting (and important) philosophical questions
E.g. the mind body problem, what is consciousness etc.

Possible Approaches

Different approaches due to different criteria, two dimensions:
Thought processes/reasoning vs. behavior/action
Success according to human standards vs. success according to an ideal concept of intelligence: rationality

Think well

Develop formal models of knowledge representation, reasoning, learning, memory, problem solving, that can be rendered in algorithms.

There is often an emphasis on systems that are probably correct, and guarantee finding an optimal solution.

Act well

For a given set of inputs, generate an appropriate output that is not necessarily correct but gets the job done

A heuristic (heuristic rule, heuristic method) is a rule of thumb, strategy, trick, simplification, or any other kind of device which drastically limits search for solutions in large problem spaces

Heuristics do not guarantee optimal solutions or any solution at all; a useful heuristic merely offers solutions which are good enough most of the time
Think like humans

Cognitive science approach, focus not just on behavior and I/O but also look at the reasoning process. Computational model should reflect "how" results were obtained.

Provide a new language for expressing cognitive theories and new mechanisms for evaluating them

GPS (General Problem Solver): Goal is not just to produce humanlike behavior (like ELIZA), but to produce a sequence of steps of the reasoning process that are similar to the steps followed by a person in solving the same task.

Act like humans

Behaviorist approach.

Not interested in how you get results, just the similarity to what human results are.

Exemplified by the Turing Test (Alan Turing, 1950).

A Brief History of AI

1943 Walter Pitts and Warren McCulloch showed how artificial neural networks could compute, relying on the use of feedback loops.

1945 John von Neumann designed the basic computer architecture still used today, in which the memory stores instructions as well as data, and instructions are executed serially. Described in his 1945 paper.

1948 Norbert Wiener published Cybernetics, a landmark book on information theory. "Cybernetics" means "the science of control and communication in the animal and the machine."

1949 Donald O. Hebb suggested a way in which artificial neural networks might learn.
**AI History**

1950  Turing proposed his test to recognize machine intelligence.
1951  Marvin Minsky and Dean Edmonds build the first artificial neural network that simulated a rat finding its way through a maze.
1956  Birth of AI. Darmouth Workshop bringing together top minds on automata theory, neural nets and the study of intelligence.
52-69  Great Expectations
      Newell & Simon Problem Solver, McCarthy LISP, Minsky Blocks world, Samuel Checkers program etc.

66-73  AI discovers computational complexity and progress slows down. Neural network research almost disappears.
69-70  Revival in AI research through knowledge-based systems. E.g. Expert systems.
80-...  AI becomes an industry
1986  Neural networks return, parallel distributed processing
87-...  AI becomes a science
1990  Emergence of intelligent agents

**1950 Turing Test**

Alan Turing (1950)
"Can machines think?" \rightarrow "Can machines behave intelligently?"
Operational test for intelligent behavior: the Imitation Game

Separate rooms contain a person, a computer, and an interrogator. The interrogator can communicate with the other two by teleprinter. The interrogator tries to determine which is the person and which is the machine.

The machine tries to fool the interrogator into believing that it is the person. If the machine succeeds, then we conclude that the machine can think.

**Turing Test**

Predicted that by 2000 a machine might have a 30% chance of fooling a lay person for 5 minutes

Anticipated the major arguments against AI in following 50 years

Suggested major components of AI:
Knowledge, reasoning, language understanding, learning
ELIZA

ELIZA: A program that simulated a psychotherapist interacting with a patient and successfully passed the Turing Test

Coded at MIT during 1964-1966 by Joseph Weizenbaum
First script was doctor:
  The script was a simple collection of syntactic patterns not unlike regular expressions
  Each pattern had an associated reply which might include bits of the input after simple transformations (my → your)
Weizenbaum was shocked at the reactions:
  Psychiatrists thought it had potential
  People anthropomorphized
  Many thought it solved the natural language problem

A funny ELIZA story

Soon after ELIZA's invention, copies of Weizenbaum's program were running on many computer systems.

Weizenbaum's former colleague at MIT, Daniel Bobrow, told the following story at a conference in 1969...

(At the time of the story Bobrow was across town from MIT at a company called BBN)

"One Saturday morning about 9 a.m., a BBN Vice President in charge of selling our Telcomp commercial service arrived at our PDP-1 Computer Room hoping to be able to use the computer for a demonstration.

He found a note on the PDP-1 teletype that read: "TYPE ALL MESSAGES INTO THIS TELETEYPE, AND END THEM WITH A PERIOD." This note was left there by one of the programming bums who had just succeeded in making run a LISP version of the DOCTOR program (based on ELIZA as developed by Weizenbaum).

However, the VP thought that this note indicated that this teletype was linked with the one in my home, since I often used the computer all night. Therefore, he started typing to "me", but in fact was typing to this version of the DOCTOR program. The following conversation ensued:

VP: Do you think that I can use the computer this morning?
D: WHY DO YOU ASK?
VP: I might be able to make some additional Telcomp sales.
D: WHY AREN'T YOU SURE?
VP: My prospective customers have never seen a demonstration of the system.
D: DOES THIS MEAN VERY MUCH TO YOU?
VP: Of course it does.
D: YOU SEEM VERY POSITIVE ABOUT THAT.
VP: This is ridiculous.
D: WHAT DO YOU MEAN THIS IS RIDICULOUS?
VP: Is there any reason why I can't use the computer now?
D: TELL ME MORE ABOUT YOUR PROSPECTIVE CUSTOMERS.
VP: Please dial me up on 491-1850"
Note that after the last remark the VP did not obey instructions, and left out the period.

Therefore, of course, the computer didn't answer him. This so infuriated the VP, who thought I [Bobrow] was playing games with him, that he called me up, woke me from a deep sleep, and said:

VP: Why are you being so snotty to me?
B: What do you mean why am I being so snotty to you?

The VP angrily read me the dialogue that “we” had been having, and couldn’t get any response but laughter from me. It took a while to convince him it really was the computer."

(Bobrow, 1969: 32-33; reproduced in Boden, 1978)."

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**ELIZA Interaction**

> Men are all alike.

[ELIZA]: IN WHAT WAY

> They’re always bugging us about something or other.

[ELIZA]: CAN YOU THINK OF A SPECIFIC EXAMPLE

> Well, my boyfriend made me come here.

[ELIZA]: YOUR BOYFRIEND MADE YOU COME HERE

> He says I’m depressed much of the time.

[ELIZA]: I AM SORRY TO HEAR THAT YOU ARE DEPRESSED

> It’s true that I am unhappy.

[ELIZA]: DO YOU THINK COMING HERE WILL HELP YOU NOT BE UNHAPPY

> I need some help, that much seems certain.

[ELIZA]: WHAT WOULD IT MEAN TO YOU IF YOU GOT SOME HELP

> Perhaps I could learn to get along with my mother.

[ELIZA]: TELL ME MORE ABOUT YOUR FAMILY

> My mother takes care of me.

[ELIZA]: WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU

Try it out! [http://chayden.net/eliza/Eliza.html](http://chayden.net/eliza/Eliza.html)

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**Intelligent Agents**

**Definition**

An agent perceives its environment via sensors and acts in that environment with its actuators or effectors to maximize progress towards its goals

Hence, an agent gets percepts one at a time, and maps this percept sequence to actions (one action at a time)

**Properties:**

- Autonomous
- Interacts with other agents plus the environment
- Reactive to the environment
- Pro-active (goal-directed)
Agent Types

We can split agent research into two main strands:

(1980 - 1990)
Distributed Artificial Intelligence (DAI)
Multi-Agent Systems (MAS)

(1990's - present)
Much broader notion of “agent”
  interface, reactive, mobile, information

Rational Agents

How to design this?

Agent

Environment

percepts
actions

Sensors

Effectors

A Windshield Wiper Agent

Thought Exercise: (take 5 min)
How do you design an agent that can wipe the windshields when needed?

Goals?
Percepts? (things to be perceived)
Sensors? (things to perceive with)
Effectors? (things to do with)
Actions? (things to do)
Environment?

A Windshield Wiper Agent

Goals: Keep windshields clean & maintain visibility
Percepts: Raining, Dirty
Sensors: Camera (moist sensor)
Effectors: Wipers (left, right, back)
Actions: Off, Slow, Medium, Fast
Environment: Inner city, freeways, highways, weather ...
How are Agents different from other software?

- Autonomous
  - They act on behalf of the user
- Have some level of intelligence
  - Can range from fixed rules to learning engines
  - Allows them to adapt to changes in the environment
- They aren't just reactive
  - Sometimes they are proactive
- Social ability
  - They can communicate with user, system, other agents
- May cooperate with other agents
  - Carrying out complex tasks which they can't do alone
- May migrate between systems
  - To access remote resources or to meet other agents

Rational Agents

What is rational at a given time depends on four things:
- Performance measure
- Prior environment knowledge
- Actions
- Percept sequence to date (sensors)

*A rational agent chooses whichever action maximizes the expected value of the performance measure given the percept sequence to date and prior environment knowledge*

Rationality

Rationality ≠ omniscience
- An omniscient agent knows the actual outcome of its actions.

Rationality ≠ perfection
- Rationality maximizes expected performance, while perfection maximizes actual performance.

The proposed definition requires:

- Information gathering/exploration
  - To maximize future rewards
- Learning from percepts
  - Extending prior knowledge
- Agent autonomy
  - Compensate for incorrect prior knowledge
Environments

To design a rational agent we must specify its task environment

PEAS description of the environment:
- Performance
- Environment
- Actuators
- Sensors

Environments

E.g. Fully automated taxi:
PEAS description of the environment:
- Performance
  - Safety, destination, profits, legality, comfort, …
- Environment
  - Streets/freeways, other traffic, pedestrians, weather, …
- Actuators
  - Steering, accelerating, brake, horn, speaker/display, …
- Sensors
  - Video, sonar, speedometer, engine sensors, keyboard, GPS, …

Environment types

- Fully observable vs. partially observable
- Deterministic vs. stochastic
- Episodic vs. sequential
- Static vs. dynamic
- Discrete vs. continuous
- Single-agent vs. multi-agent

Environment types

Some examples:

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Environment types

**Fully observable vs. partially observable**: an environment is fully observable when the sensors can detect all aspects that are relevant to the choice of action.

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**Deterministic vs. stochastic**: if the next environment state is completely determined by the current state and executed action, the environment is deterministic.

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Real World

Internet shopping

Solitaire
### Environment types

**Episodic vs. sequential**: In an episodic environment the agent's experience can be divided into atomic steps consisting of perceive and action pairs. Episodes are independent: the next episode doesn't depend on actions taken in previous episodes.

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**Static vs. dynamic**: If the environment can change while the agent is choosing an action, the environment is dynamic. Semi-dynamic if the agent's performance changes even when the environment remains the same.

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**Environment types**

*Discrete vs. continuous*: This distinction can be applied to the state of the environment, the way time is handled and to the percepts/actions of the agent.

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*Single-agent vs. multi-agent*: Does the environment contain other agents who are also maximizing some performance measure that depends on the current agent’s actions?

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Environment types

The environment type largely determines the agent design

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Agent Strategy

An agent’s strategy is a mapping from percept sequence to action

How to encode an agent’s strategy?
Long list of what should be done for each possible percept sequence vs. shorter specification (e.g. algorithm)

Skeleton agent

function SKELETON-AGENT (percept) returns action
  static: memory, the agent’s memory of the world
  memory ← UPDATE-MEMORY,(memory,percept)
  action ← CHOOSE-BEST-ACTION,(memory)
  memory ← UPDATE-MEMORY,(memory, action)
  return action

On each invocation, the agent’s memory is updated to reflect the new percept, the best action is chosen, and the fact that the action was taken is also stored in the memory. The memory persists from one invocation to the next.

Input = Percept, not history

NOTE: Performance measure is not part of the agent

Implementations

Simple reflex agent
Reflex agent with internal state
Agent with explicit goals
Utility-based agent

More sophisticated
Implementations

Simple reflex agents
No memory, base decisions on present alone

Reflex agents with internal states
Bases decision on internal state and percepts

Goal-based agents
Goal information needed to make decision

Utility-based agents
How well can the goal be achieved (degree of happiness)
What to do if there are conflicting goals?
Which goal should be selected if several can be achieved?

Simple reflex agent

Table lookup of condition-action pairs defining all possible condition-action rules necessary to interact in an environment

Problems
Table is still too big to generate and to store
Time-consuming to build the table
No knowledge of non-perceptual parts of the current state
Not adaptive to environment changes (rebuild table if happens)

Reflex agents with state

A reflex agent with internal state works by finding a rule whose condition matches the current situation (as defined by the percept and the stored internal state) and then doing the action associated with that rule.
Goal-based agents

Choose actions so as to achieve a (given or computed) goal, i.e. a description of desirable situations

Keeping track of the current state is often not enough
Add goals to decide which situations are good

Deliberative instead of reactive

May have to consider long sequences of possible actions before deciding if goal is achieved
Involves considerations of the future, “what will happen if I do...?” (search and planning)

More flexible than reflex agent
E.g. If environment changes for the reflex agent, the entire database of rules would have to be rewritten

Utility-based agents

Certain goals can be reached in different ways
Some are better, have a higher utility

Utility function maps a (sequence of) state(s) onto a real number

Improves on goals:
Selecting between conflicting goals
Select appropriately between several goals based on likelihood of success
Learning agents

Learning element:
Introduce improvements in performance element
Critic provides feedback on agents performance based on fixed performance standard

Performance element:
Selecting actions based on percepts
Corresponds to the previous agent programs

Problem generator:
Suggests actions that will lead to new and informative experiences
Exploration

Agent Classification

Franklin and Graesser: Is it an Agent or just a Program?: A Taxonomy of Autonomous Agents

http://www.msci.memphis.edu/~franklin/AgentProg.html

Autonomous Agents
- Biological Agents
- Robotic Agents
- Computational Agents
- Software Agents
- Artificial Life Agents
- Task-specific Agents
- Entertainment Agents
- Viruses

An agent model

Learn
- Collaborative learning agents
- Interface agents

Cooperate
- Collaborative agents

Autonomous
- Smart agents
Application Domains

Information gathering, integration  
Distributed sensors  
E-commerce  
Distributed virtual organization  
Virtual humans for training, entertainment

Agents as Interactive Characters

Some Examples

Agent-based Interactive Characters

Building entertaining agents requires the designer to think more about the user:

- How will the user perceive the character?
- How will the user interact with the character?
- How will the agent provide feedback to the user?

Lessons learned from ALIVE:

1. User interactions or gestures should be intuitive
2. Presence of guide or instructions can be helpful
3. Users accept that agents are human-like and may not have sensed something (contrasts with inanimate objects where reaction must be immediate, predictable and consistent)
4. Important to visualize the motivational and emotional state of the agent in its external features
5. For an immersive environment to be captivating, it must provide meaningful interactions to the user

ALIVE  
(Maes, Blumberg 1995)

Artificial Life Interactive Video Environment
Conversational Agents
(Cassell & Bickmore, 1998-01)

Conversational Real Estate Agent (REA)
Rea plays the role of a real estate salesperson who interacts with users to determine their needs, shows them around virtual properties, and attempts to sell them a house.
Task-oriented and socially-oriented conversation

Relational Agents
Agents to build and maintain long-term emotional relationships with their users
http://www.media.mit.edu/gnl/projects/socialrea/

Virtual Petz
(Andrew Stern, 1998)

Virtual pets
Autonomous agents
User has mouse control to touch, pet, pick up the characters, use toys/objects etc.
Characters grow over time and strive to be friends and companions to the user
Evolving social relationships with the user and each other
http://petz.ubi.com/
http://www.babyz.net/
Movie Clip

The Sims

A-Volve

Classic work of Genetic Art: a metaphor for artificial life, evolution, and gene manipulation
On a touchscreen, users sketch cross-sections of water creatures
These creatures are then projected onto a mirror positioned at the bottom of a water-filled basin
Users interact with their creatures in the pool as they grow and evolve
Video Clip
Group Activity

Working in groups of 3, do the following:

1. Think of 3 interactive agents or synthetic characters that you have encountered (these could be from a game, from an online system, helpers in a software application, etc).

2. Discuss the following:
   - What are the goals of each agent?
   - How does each agent interact with the user?
   - What is the intended value of each agent to the user?
   - Is the agent effective?

3. Present to the class