LCC 3710
Principles of Interaction Design

Class agenda:
-Readings
- Group Activity
- AI, Agents, Artificial Life

Readings

Turing, Alan (1950). "Computing Machinery and Intelligence" in *Mind, A Quarterly Review of Psychology and Philosophy*, Vol. LIX, No. 236, October 1950.

Maes, Patti (1995). "Artificial Life Meets Entertainment: Lifelike Autonomous Agents" in *Communications of the ACM*, Vol. 38, no. 11, November 1995.

Moggridge, Will Wright

What is AI?

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?

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

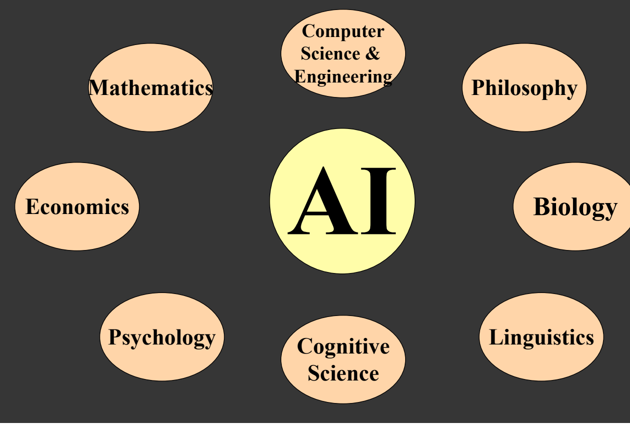
- E.g. Symbolic integration, proving theorems, playing chess, medical diagnosis etc.

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



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

	Like humans	Well
Think	General Problem Solver	Rational agents
Act	Eliza	Heuristic systems

Current AI tends to work mostly in this area

Think well

	Like humans	Well
Think	GPS	Rational agents
Act	Eliza	Heuristic systems

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

	Like humans	Well
Think	GPS	Rational agents
Act	Eliza	Heuristic systems

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

	Like humans	Well
Think	GPS	Rational agents
Act	Eliza	Heuristic systems

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

	Like humans	Well
Think	GPS	Rational agents
Act	Eliza	Heuristic systems

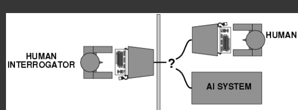
Behaviorist approach.

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

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

1950 Turing Test

Alan Turing (1950)
"Can machines think?" → "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 70% 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

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

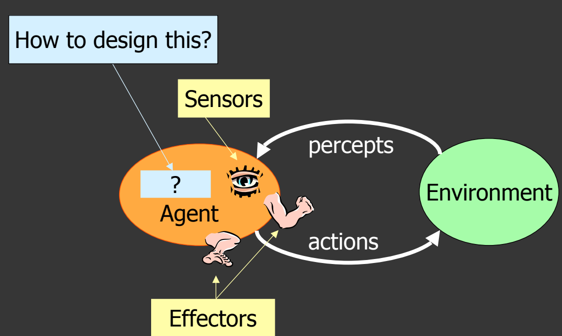
We can split agent research into two main strands:

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

(1990's – present)
Much broader notion of "agent"

- interface, reactive, mobile, information

Rational Agents



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.

Rationality

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:

- **P**erformance
- **E**nvironment
- **A**ctuators
- **S**ensors

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

Environment types

Some examples…

	Solitaire	Internet shopping	Real World
Observable?			
Deterministic?			
Episodic?			
Static?			
Discrete?			
Single-agent?			

Environment types

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

	Solitaire	Internet shopping	Real World
Observable?			
Deterministic?			
Episodic?			
Static?			
Discrete?			
Single-agent?			

Environment types

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

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?			
Episodic?			
Static?			
Discrete?			
Single-agent?			

Environment types

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

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
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Environment types

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

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?	YES	YES	NO
Episodic?			
Static?			
Discrete?			
Single-agent?			

Environment types

Episodic vs. sequential: In an episodic environment the agent's experience can be divided into atomic steps where the agents perceives and then performs A single action. The choice of action depends only on the episode itself.

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?	YES	YES	NO
Episodic?			
Static?			
Discrete?			
Single-agent?			

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. The quality of action does not depend on the previous episode.

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?	YES	YES	NO
Episodic?	NO	NO	NO
Static?			
Discrete?			
Single-agent?			

Environment types

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.

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
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Episodic?	NO	NO	NO
Static?	YES	SEMI	NO
Discrete?			
Single-agent?			

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.

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?	YES	YES	NO
Episodic?	NO	NO	NO
Static?	YES	SEMI	NO
Discrete?			
Single-agent?			

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.

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?	YES	YES	NO
Episodic?	NO	NO	NO
Static?	YES	SEMI	NO
Discrete?	YES	YES	NO
Single-agent?			

Environment types

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

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?	YES	YES	NO
Episodic?	NO	NO	NO
Static?	YES	SEMI	NO
Discrete?	YES	YES	NO
Single-agent?			

Environment types

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

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?	YES	YES	NO
Episodic?	NO	NO	NO
Static?	YES	SEMI	NO
Discrete?	YES	YES	NO
Single-agent?	YES	NO	NO

Environment types

The environment type largely determines the agent design

	Solitaire	Internet shopping	Real World
Observable?	FULL	PARTIAL	NO
Deterministic?	YES	YES	NO
Episodic?	NO	NO	NO
Static?	YES	SEMI	NO
Discrete?	YES	YES	NO
Single-agent?	YES	NO	NO

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

More sophisticated ↓

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

Implementations

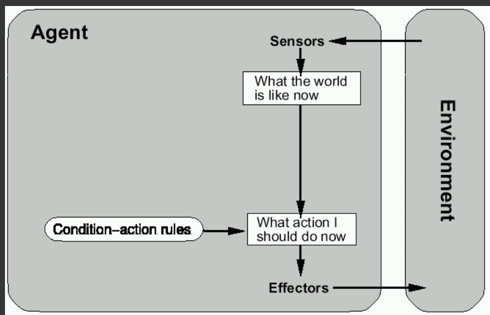
Simple reflex agents
- **No memory, base decisions on present alone**

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



A simple reflex agent works by finding a rule whose condition matches the current situation (as defined by the percept) and then doing the action associated with that rule

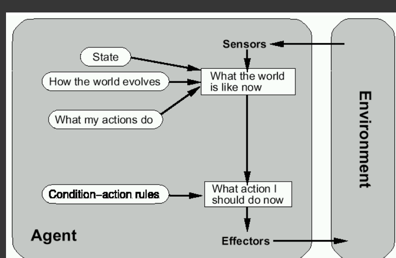
Simple reflex agent

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

Problems

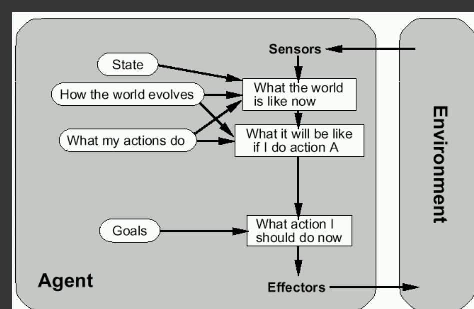
- Table is still too big to generate and to store
- Time-consuming to build the table
- No knowledge of non-perceptual parts of the current state
- Not adaptive to environment changes (rebuild table if happens)

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



Goal-based agents

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

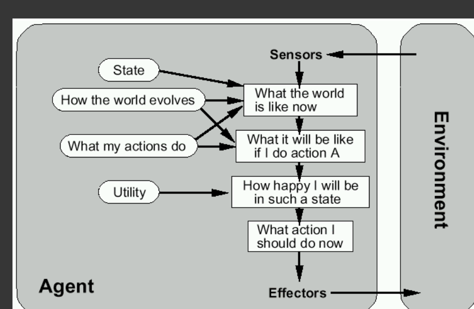
Keeping track of the current state is often not enough
- Add goals to decide which situations are good

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



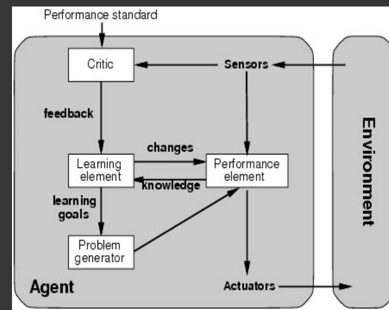
Utility-based agent

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 agents

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

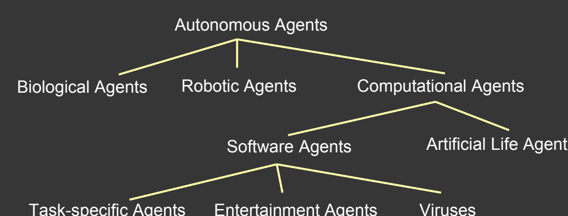
Performance element:
Selecting actions based on percepts
- Corresponds to the previous agent programs

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

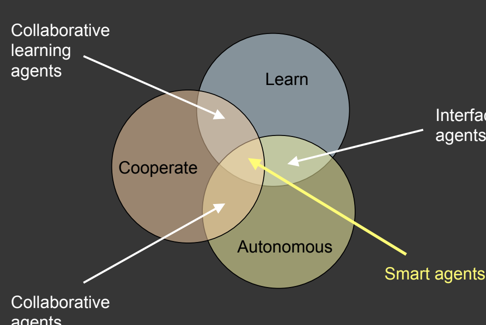
Agent Classification

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

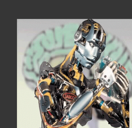
http://www.msci.memphis.edu/~franklin/AgentProg.html



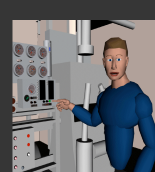
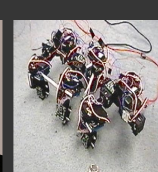
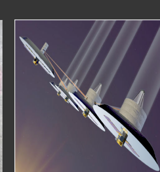
An agent model
[Nwana, 1996]



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:

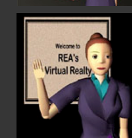
1. User interactions or gestures should be intuitive
2. Presence of guide or instructions can be helpful
3. Users accept that agents are human-like and may not have sensed something (contrasts with inanimate objects where reaction must be immediate, predictable and consistent)
4. Important to visualize 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
(PF Magic, 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/

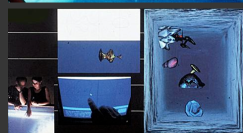
Movie Clip

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