Intelligent Agents

Chapter 2
How do you design an intelligent agent?

- **Intelligent agents** perceive environment via **sensors** and act *rationally* on them with their **effectors**
- **Discrete** agents receive **percepts** one at a time, and map them to a sequence of discrete **actions**
- General properties
  - Reactive to the environment
  - Pro-active or goal-directed
  - Interacts with other agents through communication or via the environment
  - Autonomous
Humans have

- **Sensors**: Eyes (vision), ears (hearing), skin (touch), tongue (gustation), nose (olfaction), neuromuscular system (**proprioception**)
- **Percepts**: (things that are perceived)
  - lowest level: electrical signals from these sensors
  - After processing: objects in visual field (location, textures, colors, ...), auditory streams (pitch, loudness, direction), ...
- **Effectors**: limbs, digits, eyes, tongue, ...
- **Actions**: lift finger, turn left, walk, run, carry an object, ...

Note: percepts and actions need to be carefully defined, possibly at different levels of abstraction
Example: autonomous taxi

- **Percepts**: Video, sonar, speedometer, odometer, engine sensors, keyboard input, microphone, GPS, ...
- **Actions**: Steer, accelerate, brake, horn, speak, ...
- **Goals**: Maintain safety, reach destination, maximize profits (fuel, tire wear), obey laws, provide passenger comfort, ...
- **Environment**: U.S. urban streets, freeways, traffic, pedestrians, weather, customers, ...
- **Different aspects of driving may require different types of agent programs!**
Rationality

• Ideal *rational agents* should, for each input, act to maximize expected performance measure based on
  (1) percept sequence, and
  (2) its built-in and acquired knowledge
• Rationality includes *information gathering* -- If you don’t know something, find out!
• Rationality → Need a *performance measure* to say how well a task has been achieved
• Types of performance measures: false alarm (false positive) & false dismissal (false negative) rates, speed, resources required, effect on environment, ...
Autonomy

• A system is autonomous to extent that its behavior is determined by its experience
• A system isn’t autonomous if guided by its designer according to *a priori* decisions
• An autonomous agent can always say “no”
• To survive, agents must have:
  – Enough built-in knowledge to survive
  – The ability to learn
(0) Table-driven agents
Use percept sequence/action table to find next action. Implemented by a lookup table

(1) Simple reflex agents
Based on condition-action rules, stateless devices with no memory of past world states

(2) Agents with memory
have represent states and keep track of past world states

(3) Agents with goals
Have a state and goal information describing desirable situations; can take future events into consideration

(4) Utility-based agents
base decisions on utility theory in order to act rationally
(0/1) Table-driven/reflex agent architecture

Use percept sequence/action table to find the next action. Implemented by a (large) lookup table
(0) Table-driven agents

Table lookup of percept-action pairs mapping from every possible perceived state to optimal action for it.

Problems:

– Too big to generate and to store (e.g., chess has about $10^{120}$ states)

– No knowledge of non-perceptual parts of the current state (e.g., desirability)

– Not adaptive to changes in the environment; entire table must be updated if changes occur

– Looping: Can’t make actions conditional on previous actions/states
(1) Simple reflex agents

• **Rule-based reasoning** maps percepts to optimal action; each rule handles collection of perceived states (aka reactive agents)

• **Problems**
  – Still usually too big to generate and to store
  – Still no knowledge of non-perceptual parts of state
  – Still not adaptive to changes in environment; collection of rules must be updated if changes occur
  – Still can’t condition actions on previous state
  – Difficult to engineer if the number of rules is large due to conflicts
(2) Architecture for an agent with memory

**internal state** used to keep track of past states of the world
(2) Agents with memory

- Encode *internal state* of world to remember past as contained in earlier percepts
  - Note: sensors don’t usually give entire world state at each input, so environment perception is *captured over time*
  - *State* used to encode different "world states" that generate the same immediate percept
- Requires *representing change* in the world
  - Might represent just latest state, but then can’t reason about hypothetical courses of action
(3) Architecture for goal-based agent

State and goal information describe desirable situations allowing the agent to take future events into consideration.
(3) Goal-based agents

• **Deliberative** instead of reactive
• Choose actions to achieve a goal
• Goal: description of a desirable situation
• Keeping track of current state often not enough; must add goals to decide which situations are good
• Achieving goal may require an action sequence
  – Model action consequences: “what happens if I do...?”
  – Use *planning* algorithms to produce action sequences
(4) complete utility-based agent

base decisions on utility theory in order to act rationally
(4) Utility-based agents

• For multiple possible alternatives, how to decide which is best?
• Goals give a crude distinction between happy and unhappy states, but often need a performance measure for degree
• Utility function $U: \text{State} \rightarrow \text{Reals}$ gives measure of success/happiness for given state
• Allows decisions comparing choices between conflicting goals and likelihood of success and importance of goal (if achievement uncertain)
Properties of Environments

• Fully/Partially observable
  – Agent’s sensors give complete state of environment needed to choose action: environment is fully observable
  – Such environments are convenient, freeing agents from keeping track of the environment’s changes

• Deterministic/Stochastic
  – Environment is deterministic if next state is completely determined by current state and agent’s action
  – Stochastic (i.e., non-deterministic) environments have multiple, unpredictable outcomes

• In fully observable, deterministic environments agents need not deal with uncertainty
Properties of Environments

• **Episodic/Sequential**
  – In *episodic* environments subsequent episodes don’t depend on actions in previous episodes
  – In *sequential* environments agent engages in a series of connected episodes
  – Episodic environments don’t require agent to plan ahead

• **Static/Dynamic**
  – *Static* environments doesn’t change as agent is thinking
  – The passage of time as agent deliberates is irrelevant
  – The agent needn’t observe world during deliberation
Properties of Environments III

• Discrete/Continuous
  – If number of distinct percepts and actions is limited, environment is **discrete**, otherwise it’s **continuous**

• Single agent/Multiagent
  – In environments with other agents, agent must consider strategic, **game-theoretic** aspects of environment (for either cooperative or competitive agents)
  – Most engineering environments don’t have multiagent properties, whereas most social and economic systems get their complexity from interactions of (more or less) rational agents
## Characteristics of environments

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backgammon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi driving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internet shopping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical diagnosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A **Yes** in a cell means that aspect is simpler; a **No** more complex
## Characteristics of environments

<table>
<thead>
<tr>
<th>Environment</th>
<th>Fully observable</th>
<th>Deterministic</th>
<th>Episodic</th>
<th>Static</th>
<th>Discrete?</th>
<th>Single agent?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitaire</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Backgammon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi driving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internet shopping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical diagnosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A **Yes** in a cell means that aspect is simpler; a **No** more complex
## Characteristics of environments

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitaire</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Backgammon</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Taxi driving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internet shopping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical diagnosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A **Yes** in a cell means that aspect is simpler; a **No** more complex
## Characteristics of environments

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitaire</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Backgammon</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Taxi driving</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Internet shopping</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Medical diagnosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A **Yes** in a cell means that aspect is simpler; a **No** more complex.
## Characteristics of environments

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitaire</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Backgammon</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Taxi driving</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Internet shopping</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Medical diagnosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A **Yes** in a cell means that aspect is simpler; a **No** more complex
## Characteristics of environments

→ Lots of real-world domains fall into the hardest case!

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitaire</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Backgammon</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Taxi driving</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Internet shopping</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Medical diagnosis</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

A **Yes** in a cell means that aspect is simpler; a **No** more complex
Summary

• **Agents** perceive and act in an environment, have an architecture and are implemented by an agent program

• **Ideal agents** chooses actions to maximize their expected performance, given percept sequence so far

• **Autonomous agents** use own experience rather than built-in knowledge of environment by designer
Summary

- **Agent programs** map percepts to actions and update their internal state
  - **Reflex** agents respond immediately to percepts
  - **Goal-based** agents act to achieve their goal(s)
  - **Utility-based** agents maximize their utility function

- **Representing knowledge** is important for good agent design

- Most challenging environments are **partially observable, stochastic, sequential, dynamic, and continuous** and contain multiple agents
Summary

• Not all AI problems a good fit for or require an agent model, e.g., playing solitaire
• Nor are many AI tasks you might need to solve:
  – Classify movie reviews as negative, neutral or positive
  – Locate faces of people in an image
  – Use an efficient theorem prover
  – Learn preferred thermostat settings for each hour of each day of a week