Intelligent Agents

Chapter 2
Agents and AI

• Much of our text is organized around the concept of **autonomous agents**

• It defines an agent as anything that can be viewed as perceiving its **environment** through **sensors** and acting upon that environment through **actuators**

• Not all AI problems or tasks need or fit this concept, but it’s quite general

• We’ll explore the concept today
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 → 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, $ earned, ...
Omniscience and learning

• Rational agents aren’t expected to know everything
• But to use what they do know effectively
• Rationality includes information gathering -- If you don’t know something and it might be useful, find out!
• Rationality also can exploit learning – making generalization from past experience to fill in missing information
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 \textit{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
PEAS model: Taxi Agent

- Performance, Environment, Actuators, Sensors
- Example of an autonomous taxi

<table>
<thead>
<tr>
<th>Agent Type</th>
<th>Performance Measure</th>
<th>Environment</th>
<th>Actuators</th>
<th>Sensors</th>
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<tbody>
<tr>
<td>Taxi driver</td>
<td>Safe, fast, legal, comfortable trip, maximize profits, minimize impact on other road users</td>
<td>Roads, other traffic, police, pedestrians, customers, weather</td>
<td>Steering, accelerator, brake, signal, horn, display, speech</td>
<td>Cameras, radar, speedometer, GPS, engine sensors, accelerometer, microphones, touchscreen</td>
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## PEAS model: Other Agents

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<td>Medical diagnosis system</td>
<td>Healthy patient, reduced costs</td>
<td>Patient, hospital, staff</td>
<td>Display of questions, tests, diagnoses, treatments</td>
<td>Touchscreen/voice entry of symptoms and findings</td>
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<td>Satellite image analysis system</td>
<td>Correct categorization of objects, terrain</td>
<td>Orbiting satellite, downlink, weather</td>
<td>Display of scene categorization</td>
<td>High-resolution digital camera</td>
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<td>Part-picking robot</td>
<td>Percentage of parts in correct bins</td>
<td>Conveyor belt with parts; bins</td>
<td>Jointed arm and hand</td>
<td>Camera, tactile and joint angle sensors</td>
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<tr>
<td>Refinery controller</td>
<td>Purity, yield, safety</td>
<td>Refinery, raw materials, operators</td>
<td>Valves, pumps, heaters, stirrers, displays</td>
<td>Temperature, pressure, flow, chemical sensors</td>
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<td>Interactive English tutor</td>
<td>Student’s score on test</td>
<td>Set of students, testing agency</td>
<td>Display of exercises, feedback, speech</td>
<td>Keyboard entry, voice</td>
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(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
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 of states)
– 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 remain**
  – Usually too big to generate and to store
  – No knowledge of non-perceptual parts of state
  – Not adaptive to changes in environment; collection of rules must be updated if changes occur
  – Can’t condition actions on previous state
  – Difficult to engineer if number of rules large due to conflicts
(2) Architecture for an agent with memory

Internal state keeps track of past states of the world
(2) Agents with memory

• Encode *internal state* of world to remember past as modeled by 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 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)
Problem Environments

• Characteristics of the problem environment have a big impact on an agent’s requirements

• Consider developing an agent to
  – Solve a crossword puzzle, vs.
  – Drive a Taxi

• We can identify some general characteristics to help us understand the problem and possible approaches to solving it
Properties of Environments (1)

• 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 (2)

• 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 (3)

• **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

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

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

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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