INTELLIGENT AGENTS

CHAPTER 2
Outline

♦ Agents and environments
♦ Rationality
♦ PEAS (Performance measure, Environment, Actuators, Sensors)
♦ Environment types
♦ Agent types
Agents include humans, robots, softbots, thermostats, etc.

The agent function maps from percept histories to actions:

\[ f : \mathcal{P}^* \rightarrow A \]

The agent program runs on the physical architecture to produce \( f \)
Vacuum-cleaner world

Percepts: location and contents, e.g., $[A, \text{Dirty}]$

Actions: Left, Right, Suck, NoOp
## A vacuum-cleaner agent

<table>
<thead>
<tr>
<th>Percept sequence</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A, Clean]</td>
<td>Right</td>
</tr>
<tr>
<td>[A, Dirty]</td>
<td>Suck</td>
</tr>
<tr>
<td>[B, Clean]</td>
<td>Left</td>
</tr>
<tr>
<td>[B, Dirty]</td>
<td>Suck</td>
</tr>
<tr>
<td>[A, Clean], [A, Clean]</td>
<td>Right</td>
</tr>
<tr>
<td>[A, Clean], [A, Dirty]</td>
<td>Suck</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

function **Reflex-Vacuum-Agent** ([location, status]) returns an action

```plaintext
if status = Dirty then return Suck
else if location = A then return Right
else if location = B then return Left
```

What is the **right** function?
Can it be implemented in a small agent program?
Rationality

Fixed performance measure evaluates the environment sequence
– one point per square cleaned up in time $T$?
– one point per clean square per time step, minus one per move?
– penalize for $> k$ dirty squares?

A rational agent chooses whichever action maximizes the expected value of the performance measure given the percept sequence to date

Rational $\neq$ omniscient
– percepts may not supply all relevant information
Rational $\neq$ clairvoyant
– action outcomes may not be as expected
Hence, rational $\neq$ successful

Rational $\Rightarrow$ exploration, learning, autonomy
To design a rational agent, we must specify the task environment.

Consider, e.g., the task of designing an automated taxi:

**Performance measure**

**Environment**

**Actuators**

**Sensors**
To design a rational agent, we must specify the **task environment**

Consider, e.g., the task of designing an automated taxi:

**Performance measure**?? safety, destination, profits, legality, comfort, . . .

**Environment**?? US streets/freeways, traffic, pedestrians, weather, . . .

**Actuators**?? steering, accelerator, brake, horn, speaker/display, . . .

**Sensors**?? video, accelerometers, gauges, engine sensors, keyboard, GPS, . . .
Internet shopping agent

Performance measure

Environment

Actuators

Sensors
Internet shopping agent

**Performance measure**?? price, quality, appropriateness, efficiency

**Environment**?? current and future WWW sites, vendors, shippers

**Actuators**?? display to user, follow URL, fill in form

**Sensors**?? HTML pages (text, graphics, scripts)
### Environment types

<table>
<thead>
<tr>
<th>Observable</th>
<th>Deterministic</th>
<th>Episodic</th>
<th>Static</th>
<th>Discrete</th>
<th>Single-agent</th>
<th>Solitaire</th>
<th>Backgammon</th>
<th>Internet shopping</th>
<th>Taxi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment Types</td>
<td>Solitaire</td>
<td>Backgammon</td>
<td>Internet Shopping</td>
<td>Taxi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------</td>
<td>------------</td>
<td>-------------------</td>
<td>------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observable??</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deterministic??</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Episodic??</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static??</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discrete??</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-agent??</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment type</td>
<td>Solitaire</td>
<td>Backgammon</td>
<td>Internet shopping</td>
<td>Taxi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>------------</td>
<td>-------------------</td>
<td>------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observable</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deterministic</td>
<td>Yes</td>
<td>No</td>
<td>Partly</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Episodic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-agent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Environment types

<table>
<thead>
<tr>
<th>Observable</th>
<th>Deterministic</th>
<th>Episodic</th>
<th>Static</th>
<th>Discrete</th>
<th>Single-agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Partly</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solitaire</th>
<th>Backgammon</th>
<th>Internet shopping</th>
<th>Taxi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Partly</td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
## Environment types

<table>
<thead>
<tr>
<th></th>
<th>Solitaire</th>
<th>Backgammon</th>
<th>Internet shopping</th>
<th>Taxi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observable??</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Deterministic??</td>
<td>Yes</td>
<td>No</td>
<td>Partly</td>
<td>No</td>
</tr>
<tr>
<td>Episodic??</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Static??</td>
<td>Yes</td>
<td>Semi</td>
<td>Semi</td>
<td>No</td>
</tr>
<tr>
<td>Discrete??</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-agent??</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Environment types

<table>
<thead>
<tr>
<th></th>
<th>Solitaire</th>
<th>Backgammon</th>
<th>Internet shopping</th>
<th>Taxi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observable</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Deterministic</strong></td>
<td>Yes</td>
<td>No</td>
<td>Partly</td>
<td>No</td>
</tr>
<tr>
<td><strong>Episodic</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Static</strong></td>
<td>Yes</td>
<td>Semi</td>
<td>Semi</td>
<td>No</td>
</tr>
<tr>
<td><strong>Discrete</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Single-agent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Environment types

<table>
<thead>
<tr>
<th></th>
<th>Solitaire</th>
<th>Backgammon</th>
<th>Internet shopping</th>
<th>Taxi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observable??</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Deterministic??</strong></td>
<td>Yes</td>
<td>No</td>
<td>Partly</td>
<td>No</td>
</tr>
<tr>
<td><strong>Episodic??</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Static??</strong></td>
<td>Yes</td>
<td>Semi</td>
<td>Semi</td>
<td>No</td>
</tr>
<tr>
<td><strong>Discrete??</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Single-agent??</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes (except auctions)</td>
<td>No</td>
</tr>
</tbody>
</table>

The environment type largely determines the agent design

The real world is (of course) partially observable, stochastic, sequential, dynamic, continuous, multi-agent
Agent types

Four basic types in order of increasing generality:
- simple reflex agents
- reflex agents with state
- goal-based agents
- utility-based agents

All these can be turned into learning agents
Simple reflex agents

Agent

Sensors

What the world is like now

Condition–action rules

What action I should do now

Actuators

Environment
Example

**function** REFLEX-VACUUM-AGENT([location, status]) **returns** an action

   if status = Dirty then return Suck
   else if location = A then return Right
   else if location = B then return Left

(setq joe (make-agent :name 'joe :body (make-agent-body)
                       :program (make-reflex-vacuum-agent-program)))

(defun make-reflex-vacuum-agent-program ()
  #'(lambda (percept)
      (let ((location (first percept)) (status (second percept)))
        (cond ((eq status 'dirty) 'Suck)
               ((eq location 'A) 'Right)
               ((eq location 'B) 'Left))))
Reflex agents with state

Agent

- State
- How the world evolves
- What my actions do
- Condition–action rules

Environment

- Sensors
- What the world is like now

- What action I should do now

Actuators
Example

**function** Reflex-Vacuum-Agent([location, status]) **returns** an action

**static:** last_A, last_B, numbers, initially ∞

if status = Dirty then . . .

```
(defun make-reflex-vacuum-agent-with-state-program ()
  (let ((last-A infinity) (last-B infinity))
    #'(lambda (percept)
        (let ((location (first percept)) (status (second percept)))
          (incf last-A) (incf last-B)
          (cond
            ((eq status 'dirty)
              (if (eq location 'A) (setq last-A 0) (setq last-B 0)) 'Suck)
            ((eq location 'A) (if (> last-B 3) 'Right 'NoOp))
            ((eq location 'B) (if (> last-A 3) 'Left 'NoOp)))))))
```
Goal-based agents

**Agent**

- State
- How the world evolves
- What my actions do
- Goals

**Environment**

- Sensors
- What the world is like now
- What it will be like if I do action A
- What action I should do now

**Actuators**
Utility-based agents

Agent

Environment

State

What the world is like now

What it will be like if I do action A

How happy I will be in such a state

What action I should do now

How the world evolves

What my actions do

Utility

Sensors

Actuators
Learning agents

Performance standard

Agent

Environment

Critic

Sensors

Performance element

feedback

changes

knowledge

learning goals

Problem generator

Actuators

Chapter 2
Summary

Agents interact with environments through actuators and sensors

The agent function describes what the agent does in all circumstances

The performance measure evaluates the environment sequence

A perfectly rational agent maximizes expected performance

Agent programs implement (some) agent functions

PEAS descriptions define task environments

Environments are categorized along several dimensions:

Several basic agent architectures exist:
  reflex, reflex with state, goal-based, utility-based