Artificial Intelligence

2. Intelligent Agents

On the Structure of Intelligent Agents and their Environments

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Agenda

1. What is an Agent?

2. What is a Rational Agent?

3. Different Classes of Agents

4. Different Types of Environments
Agents

- Perceive the environment through sensors (\(\rightarrow\) Percepts)
- Act upon the environment through actuators (\(\rightarrow\) Actions)

Examples: Humans and animals, robots and software agents (softbots), temperature control, ABS, \ldots
Rational Agents

... do the “right thing”!

In order to evaluate their performance, we have to define a \textit{performance measure}. Autonomous vacuum cleaner example:

- $m^2$ per hour
- Level of cleanliness
- Energy usage
- Noise level
- Safety (behavior towards hamsters/small children)

Optimal behavior is often unattainable!

- Not all relevant information is perceivable
- Complexity of the problem is too high
Rationality vs. Omniscience

- An omniscient agent knows the actual effects of its actions.

- In comparison, a rational agent behaves according to its percepts and knowledge and attempts to maximize the expected performance.

- Example?
The Ideal Rational Agent

Rational behavior depends on:
- Performance measures (goals);
- Percept sequences;
- Knowledge of the environment;
- Possible actions.

Ideal rational agent

For each possible percept sequence, a rational agent should select an action that is expected to maximize its performance measure, given the evidence provided by the percept sequence and whatever built-in knowledge the agent has.

Percept Sequence $\times$ World Knowledge $\rightarrow$ Action

Active perception is necessary to avoid trivialization!
### Examples of Agents: PEAS Descriptions

<table>
<thead>
<tr>
<th>Agent Type</th>
<th>Performance Measure</th>
<th>Environment</th>
<th>Actuators</th>
<th>Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical diagnosis system</td>
<td>healthy patient, costs, lawsuits</td>
<td>patient, hospital, staff</td>
<td>display questions, tests, diagnoses, treatments, referrals</td>
<td>keyboard entry of symptoms, findings, patient’s answers</td>
</tr>
<tr>
<td>Satellite image analysis system</td>
<td>correct image categorization</td>
<td>downlink from orbiting satellite</td>
<td>display categorization of scene</td>
<td>color pixel arrays</td>
</tr>
<tr>
<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, joint angle sensors</td>
</tr>
<tr>
<td>Refinery controller</td>
<td>purity, yield, safety</td>
<td>refinery, operators</td>
<td>valves pumps, heaters displays</td>
<td>temperature, pressure, chemical sensors</td>
</tr>
<tr>
<td>Interactive English tutor</td>
<td>student’s score on test</td>
<td>set of students, testing agency</td>
<td>display exercises, suggestions, corrections</td>
<td>keyboard entry</td>
</tr>
</tbody>
</table>
Structure of Rational Agents

Realization of the ideal mapping through an

- **Agent program**, executed on an
- **Architecture** which also provides an interface to the environment (percepts, actions).

→ Agent = Architecture + Program
Questionnaire

Question!

Which are Agents?

(A): James Bond.  
(B): Vacuum cleaner.  
(C): Your dog.  
(D): Thermometer.
Who is rational?

(A): James Bond, crossing the street after looking.

(C): Your dog, crossing the street after not looking.

(B): Vacuum cleaner, deciding to clean under your bed.

(D): Thermometer, not doing anything.
The Simplest Design: Table-Driven Agents

function TABLE-DRIVEN-AGENT(\textit{percept}) returns an action

\textbf{persistent:} \textit{percepts}, a sequence, initially empty

\textit{table}, a table of actions, indexed by percept sequences, initially fully specified

append \textit{percept} to the end of \textit{percepts}

\textit{action} $\leftarrow$ LOOKUP(\textit{percepts, table})

\textbf{return} \textit{action}

Problems:

- The table can become very large.
- It usually takes a very long time for the designer to specify it.
- ... practically impossible!
Direct use of perceptions is often not possible due to the large space required to store them (e.g., video images).

Input therefore is often interpreted before decisions are made.
Interpretative Reflex Agents

Since storage space required for actual perceptions is too large, interpret perceptions:

```plaintext
function SIMPLE-REFLEX-AGENT( percept) returns an action
persistent: rules, a set of condition–action rules

state ← INTERPRET-INPUT( percept)
rule ← RULE-MATCH( state, rules)
action ← rule.ACTION
return action
```
In case the agent’s history in addition to the actual percept is required to decide on the next action, it must be represented in a suitable form:
function MODEL-BASED-REFLEX-AGENT(percept) returns an action

persistent: state, the agent’s current conception of the world state
model, a description of how the next state depends on current state and action
rules, a set of condition–action rules
action, the most recent action, initially none

state ← UPDATE-STATE(state, action, percept, model)
rule ← RULE-MATCH(state, rules)
action ← rule.ACTION
return action
Often, **percepts alone are insufficient** to decide what to do.

This is because the correct action depends on the given **explicit goals** (e.g., go towards X).

The **model-based, goal-based agents** use an explicit representation of goals and consider them for the choice of actions.
Model-based, 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

Agent Classes

- Model-based, Goal-based Agents
Usually, there are several possible actions that can be taken in a given situation.

In such cases, the utility of the next achieved state can come into consideration to arrive at a decision.

A utility function maps a state (or a sequence of states) onto a real number.

The agent can also use these numbers to weigh the importance of competing goals.
Model-based, Utility-based Agents

- Agent
- Environment
- Sensors
- State
  - How the world evolves
- Utility
  - What my actions do
- Actuators
  - What action I should do now
- 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
Learning Agents

- Learning agents can become more competent over time.
- They can start with an initially empty knowledge base.
- They can operate in initially unknown environments.
Components of Learning Agents

- **Learning element** (responsible for making improvements).
- **Performance element** (has to select external actions).
- **Critic** (determines the performance of the agent).
- **Problem generator** (suggests actions that will lead to informative experiences).
Learning Agents

- **Agent**: Contains a problem generator and learning goals.
- **Environment**: Accepts feedback and changes knowledge.
- **Performance standard**: Defines the criteria for success.
- **Critic**: Evaluates the performance of the learning elements.
- **Learning element**: Receives feedback and changes knowledge.
- **Sensors**: Provide information about the environment.
- **Actuators**: React to changes in the environment.

The diagram illustrates the interaction between the agent, environment, and learning components, focusing on the process of learning and adaptation.
Questionnaire

Question!

What kind of agent are you?

(A): Table-Driven.  
(C): Utility-Based.  
(B): Reflex Agent.  
(D): Learning.
Questionnaire, ctd.

Question!

When are reflexes not good enough?

(A): Your goals are not always the same.

(B): Your goals are rather complicated.

(C): The world takes time to interpret.

(D): Your capabilities should grow over time.
The Environment of Rational Agents

- **Accessible vs. inaccessible (fully observable vs. partially observable)**
  
  Are the relevant aspects of the environment accessible to the sensors?

- **Deterministic vs. stochastic**
  
  Is the next state of the environment completely determined by the current state and the selected action?

  If the only non-determinism are actions of other agents, the environment is called strategic.

- **Episodic vs. sequential**
  
  Can the quality of an action be evaluated within an episode (perception + action), or are future developments decisive?
The Environment of Rational Agents, ctd.

- **Static vs. dynamic**
  
  *Can the environment change while the agent is deliberating?*
  
  If the environment does not change, but the agent’s performance score changes, the environment is called **semi-dynamic**.

- **Discrete vs. continuous**
  
  *Is the environment discrete (e.g., chess) or continuous (e.g., a robot moving in a room)?*

- **Single agent vs. multi-agent**
  
  *Is there just one agent, or several of them?*
  
  There are **competitive** and **cooperative** multi-agent scenarios.
### Examples of Environments

<table>
<thead>
<tr>
<th>Task</th>
<th>Observable</th>
<th>Deterministic</th>
<th>Episodic</th>
<th>Static</th>
<th>Discrete</th>
<th>Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chess with a clock</td>
<td>fully</td>
<td>strategic</td>
<td>sequential</td>
<td>semi</td>
<td>discrete</td>
<td>multi</td>
</tr>
<tr>
<td>Poker</td>
<td>partially</td>
<td>stochastic</td>
<td>sequential</td>
<td>static</td>
<td>discrete</td>
<td>multi</td>
</tr>
<tr>
<td>Backgammon</td>
<td>fully</td>
<td>stochastic</td>
<td>sequential</td>
<td>static</td>
<td>discrete</td>
<td>multi</td>
</tr>
<tr>
<td>Taxi driving</td>
<td>partially</td>
<td>stochastic</td>
<td>sequential</td>
<td>dynamic</td>
<td>continuous</td>
<td>multi</td>
</tr>
<tr>
<td>Medical diagnosis</td>
<td>partially</td>
<td>stochastic</td>
<td>sequential</td>
<td>dynamic</td>
<td>continuous</td>
<td>single</td>
</tr>
<tr>
<td>Image analysis</td>
<td>fully</td>
<td>deterministic</td>
<td>episodic</td>
<td>semi</td>
<td>continuous</td>
<td>single</td>
</tr>
<tr>
<td>Part-picking robot</td>
<td>partially</td>
<td>stochastic</td>
<td>episodic</td>
<td>dynamic</td>
<td>continuous</td>
<td>single</td>
</tr>
<tr>
<td>Refinery controller</td>
<td>partially</td>
<td>stochastic</td>
<td>sequential</td>
<td>dynamic</td>
<td>continuous</td>
<td>single</td>
</tr>
<tr>
<td>Interactive English tutor</td>
<td>partially</td>
<td>stochastic</td>
<td>sequential</td>
<td>dynamic</td>
<td>discrete</td>
<td>multi</td>
</tr>
</tbody>
</table>
Questionnaire

Question!

James Bond’s environment is?

Questionnaire, ctd.

**Question!**

**Your own environment is?**


Summary

- An **agent** is something that perceives and acts. It consists of an architecture and an agent program.

- An **ideal rational agent** always takes the action that maximizes its performance given the percept sequence and its environment knowledge.

- There are a variety of agent designs:
  - Reflex agents respond immediately to percepts.
  - Goal-based agents work towards goals.
  - Utility-based agents try to maximize their reward.
  - Learning agents improve their behavior over time.

- Some **environments** are more demanding than others . . .

- . . . your own, and that of James Bond, are the most difficult.