Artificial Intelligence

2. Intelligent Agents

Let's Get a Little Orientation Here

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Agenda

Introduction

→ A central aspect of intelligence (and one possible way to define it) is the ability to act successfully in the world (cf. **Chapter 1**).

This chapter provides a broad categorization of, and terminology for, talking about that:

- Useful for a research field to establish a common language.
- Useful for you to get a rough overview.

→ We'll think a bit about what it means to "behave rationally", what are possible architectures for achieving such behavior with a computer, and what are relevant properties of the world we need to act in.

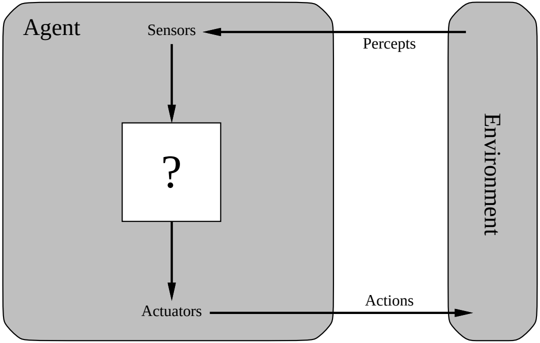
Disclaimer

→ The concepts and explanations in this chapter are very broad and superficial. In the remainder of the course, we will consider in detail particular problems relating to decision-making, and specify algorithms for solving these.

What is an "Agent" in AI?

Agents:

- Perceive the environment through sensors ($\rightarrow$ percepts).
- Act upon the environment through actuators ($\rightarrow$ actions).



$\rightarrow$ Examples? Humans, animals, robots, software agents (softbots), ...

Rational Agents . . .

. . . do "the right thing"!

→ Meaning of "do the right thing": Rational agents select their actions so as to maximize a performance measure.

→ What's the performance measure of an autonomous vacuum cleaner?

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

→ But what if the vacuum cleaner's sensors are not good enough to recognize the difference between a hamster and a shoe?

Actually, Rational Agents . . .

. . . ATTEMPT to do "the right thing"!

→ The hypothetical best case ("the right thing") is often unattainable.

→ The agent might not be able to perceive all relevant information. (Is there dirt under this bed? Is this a hamster or a shoe?)

Rationality vs. Omniscience:

- An omniscient agent knows everything about the enviroment, and knows the actual effects of its actions.
- A rational agent just makes the best of what it has at its disposal, *maximizing expected performance given its percepts and knowledge*.

→ Example? I check the traffic before crossing the street. As I cross, I am hit by a meteorite. Was I lacking rationality?

So, What *Is* a Rational Agent?

Mapping your input to the best possible output:

Performance measure M $\times$ Percepts P $\times$ Knowledge K $\rightarrow$ Action a

- An agent has a performance measure M and a set A of possible actions. Given a percept sequence P, as well as knowledge K about the world, it selects an action $a \in A$.
- The action a is optimal if it maximizes the expected value of M, given the evidence provided by P and K. The agent is rational if it always chooses an optimal a.

$\rightarrow$ If the vacuum cleaner bumps into the Hamster, then this can be rational in case the percept does not allow to recognize the hamster.

$\rightarrow$ Note: If observation actions are required, they are elements of A, i.e., the agent must *perceive actively*. Example: *"truck-approaching"* $\notin P$ *but I didn't look to check* $\implies$ *I am NOT being rational!*

A Rational Agent is an Optimal Action Choice Function?

We also need to realize the agent, through:

- an agent program, executed on
- an architecture which also provides an interface to the environment (percepts, actions).

→ Agent = Architecture + Program.

Practical limitations:

- Our definition captures limitations on percepts and knowledge.
- It does not capture computational limitations (often, determining an optimal choice would take too much time/memory).

  → In practice, we often *approximate* the rational decision: bounded rationality.

Examples of Agents: PEAS Descriptions

Agent Type	Performance Measure	Environment	Actuators	Sensors
Chess/Go player	win/lose/draw	game board	moves	board position
Medical diagnosis system	accuracy of diagnosis	patient, staff	display questions, diagnoses	keyboard entry of symptoms
Part-picking robot	percentage of parts in correct bins	conveyor belt with parts, bins	jointed arm and hand	camera, joint angle sensors
Refinery controller	purity, yield, safety	refinery, operators	valves pumps, heaters displays	temperature, pressure, chemical sensors
Interactive English tutor	student's score on test	set of students, testing agency	display exercises, suggestions, corrections	keyboard entry

Questionnaire

Question!

Which are agents?

(A): James Bond.

(B): Your dog.

(C): Vacuum cleaner.

(D): Thermometer.

Question!

Who is rational?

(A): James Bond, crossing the street without looking.

(B): Your dog, crossing the street without looking.

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

(D): Thermostat, deciding to cool down your fridge.

Questionnaire Answers

First Question: Which are agents?

→ (A) and (B): Definite yes.

→ (C): Yes, if it's an autonomous vacuum cleaner. Else, no.

→ (D): No, because it cannot do anything. (Changing the displayed temperature value could be considered an "action", but that is not the intended usage of the term.)

Second Question: Who is rational?

→ (A): Depends on whether safety is part of his performance measure.

→ (B): Depends on whether or not we consider dogs to be able to check the traffic. If they can't, then just running over could be optimal (e.g. to meet fellow dogs or grab a sausage).

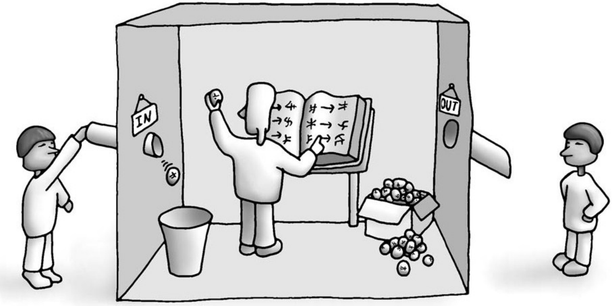
→ (C): Yes. (Hypothetical best-case if it's dirty under your bed, and you're not currently sleeping in it.)

→ (D): Not clear whether a thermostat is an agent. On the one hand, in difference to the Thermometer, the Thermostat takes an action. On the other hand, in a classical Thermostat the "action decision" is just a physical reaction (like a solar panel that produces electricity if the sun shines).

Table-Driven Agents

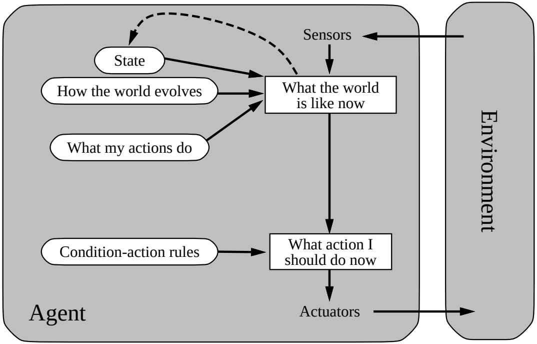
function TABLE-DRIVEN-AGENT(*percept*) **returns** an action
  persistent: *percepts*, a sequence, initially empty
    table, a table of actions, indexed by percept sequences, initially fully specified

  append *percept* to the end of *percepts*
  action ← LOOKUP(*percepts*, *table*)
  return *action*



Reflex Agents

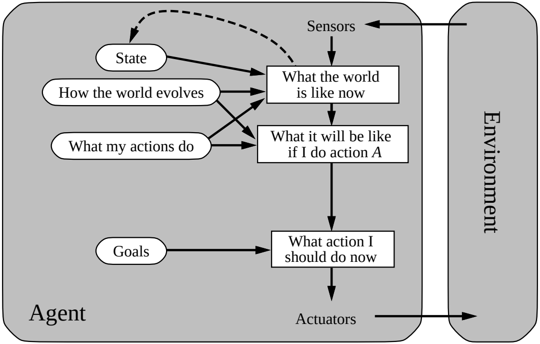
More useful, but still very simple, method for choosing actions: **Condition-Action Rules** (note: raw sensor data *interpreted*, using a *world model*, prior to evaluating the rules)



→ Example? Vacuum cleaner: If it's dirty where you are right now, clean; otherwise, move somewhere else randomly.

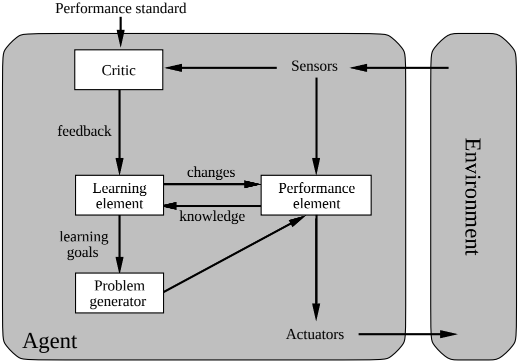
Goal-Based Agents (Belief-Desire-Intention)

Often, doing the right thing requires considering the future:



→ Example? If you're driving a car, then, at any one crossing you get to, whether you go left/right/straight (or U-turn) depends on where you want to get to.

Learning Agents



- Critic: Measures performance.
- Learning element: Learns new knowledge.
- Performance element: Selects actions (RL: exploitation).
- Problem generator: Suggests actions favoring informative learning experiences (RL: exploration).

Domain-Specific vs. General Agents

vs.

Solver specific to a particular problem ("domain").	**vs.**	Solver based on *description* in a general problem-description language (e.g., the rules of any board game).
More efficient.	**vs.**	More *intelligent*.

Questionnaire

Question!

What kind of agent are you?

(A): Table-Driven

(B): Reflex Agent

(C): Learning

(D): Domain-Specific

→ (A): Definite no, humans don't look up their actions from a full percepts history.

→ (B): In some basic aspects yes (closing the eyelids). Typically, no since most of the things we do are more complicated (e.g., answering these questions here).

→ (C): In many aspects yes (e.g., learning to walk and speak, getting a driving license, studying CS). In some no (closing the eyelids).

→ (D): A distinguishing quality of humans is that we are *not* domain-specific. We can (learn to) deal with arbitrary problems we're confronted with.

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 or continuous?

- 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

Task	Observable	Deterministic	Episodic	Static	Discrete	Agents
Chess/Go without clock	fully	strategic	sequential	static	discrete	multi
Poker	partially	stochastic	sequential	static (?)	discrete	multi
Car driving	partially	stochastic	sequential	dynamic	continuous	multi
Medical diagnosis	partially	stochastic	episodic	dynamic	continuous	single
Image analysis	fully	deterministic	episodic	semi	continuous	single
Part-picking robot	partially	stochastic	episodic	dynamic	continuous	single
Refinery controller	partially	stochastic	sequential	dynamic	continuous	single
Interactive English tutor	partially	stochastic	sequential	dynamic	discrete	multi

→ These properties may depend on the design: E.g., if the medical diagnosis system interacts with skeptical staff then it's multi-agent, and if we take into account the overall treatment then it's sequential.

Questionnaire

Question!

James Bond's environment is?

(A): Fully Observable. (B): Episodic.

(C): Static. (D): Single-Agent.

Question!

Your own environment is?

(A): Fully Observable. (B): Episodic.

(C): Static. (D): Single-Agent.

Questionnaire Answers

First Question: James Bond's environment is?

→ (A) Fully Observable: Definitely not! Else Bond would always know immediately what the bad guys are up to.

→ (B) Episodic: Definitely not. Every one of Bond's "actions" would be "rewarded" separately and independently. The "film plot" would consist of saving/not-saving the world about every 2 minutes.

→ (C) Static: Definitely not. Just imagine Bond standing there, thinking, while the bad guys release Godzilla in NYC (or whatever else they may be up to).

→ (D) Single-Agent: Definitely not. A Bond film without bad guys would be boring.

Second Question: Your own environment is?

→ (A) Fully Observable: No. E.g., you don't know what the exam questions will be.

→ (B) Episodic: No. E.g., it takes more than one action to complete your studies.

→ (C) Static: No. E.g., if you take a year to decide how to prepare for the exam, it'll be over by the time you're done.

→ (D) Single-Agent: No. Apart from your family etc., for example at some point you will compete for the same job with somebody else.

Classifying AI Areas

Many sub-areas of AI can be classified by:

- Domain-specific vs. general.
- The environment.
- (Particular agent architectures sometimes also play a role, especially in Robotics.)

→ The same is true of the sub-topics in this course. The focus is on general methods (a bias in much of the AI field), and simple environments (after all, it's an introductory course only).

→ Up next: A rough classification of our topics, in these terms.

Classifying AI Areas: Our Topics

Classical Search

Environment:

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

Approach:

- Domain-specific vs. general.

Classifying AI Areas: Our Topics

Planning

Environment:

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

Approach:

- Domain-specific vs. general.

→ Planning formalisms and approaches exist also for any and all of partial observability, and stochastic/dynamic/continuous/multi-agent settings.

Classifying AI Areas: Our Topics

Adversarial Search

Environment:

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

Approach:

- Domain-specific vs. general.

→ Adversarial search formalisms and approaches exist also for partial observability and stochastic settings.

Classifying AI Areas: Our Topics

General Game Playing (not in the 2022 edition of the course)

Environment:

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

Approach:

- Domain-specific vs. general.

$\rightarrow$ General game playing formalisms and approaches exist also for partial observability and stochastic settings.

Classifying AI Areas: Our Topics

Constraint Satisfaction & Reasoning

Environment:

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

Approach:

- Domain-specific vs. general.

Classifying AI Areas: Our Topics

Probabilistic Reasoning (not covered in this course)

Environment:

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

Approach:

- Domain-specific vs. general.

Summary

- An agent is something that perceives and acts. It consists of an architecture and an agent program.
- A rational agent always takes the action that maximizes its expected performance, subject to the percept sequence and its environment knowledge.
- There are a variety of agent designs:
  - Reflex agents respond to percepts by condition-action rules.
  - Goal-based agents work towards goals.
  - Utility-based agents make trade-offs using a utility function.
  - 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.

Reading

- *Chapter 2: Intelligent Agents* [Russell and Norvig (2010)].

  Content: A much more detailed description of the subjects I overviewed here (agents, agent architectures, environments). Just as broad and superficial, though.

References I

Stuart Russell and Peter Norvig. *Artificial Intelligence: A Modern Approach (Third Edition)*. Prentice-Hall, Englewood Cliffs, NJ, 2010.