CS 5/7320 Artificial Intelligence

Intelligent Agents AIMA Chapter 2

Slides by Michael Hahsler
based on slides by Svetlana Lazepnik
with figures from the AIMA textbook.

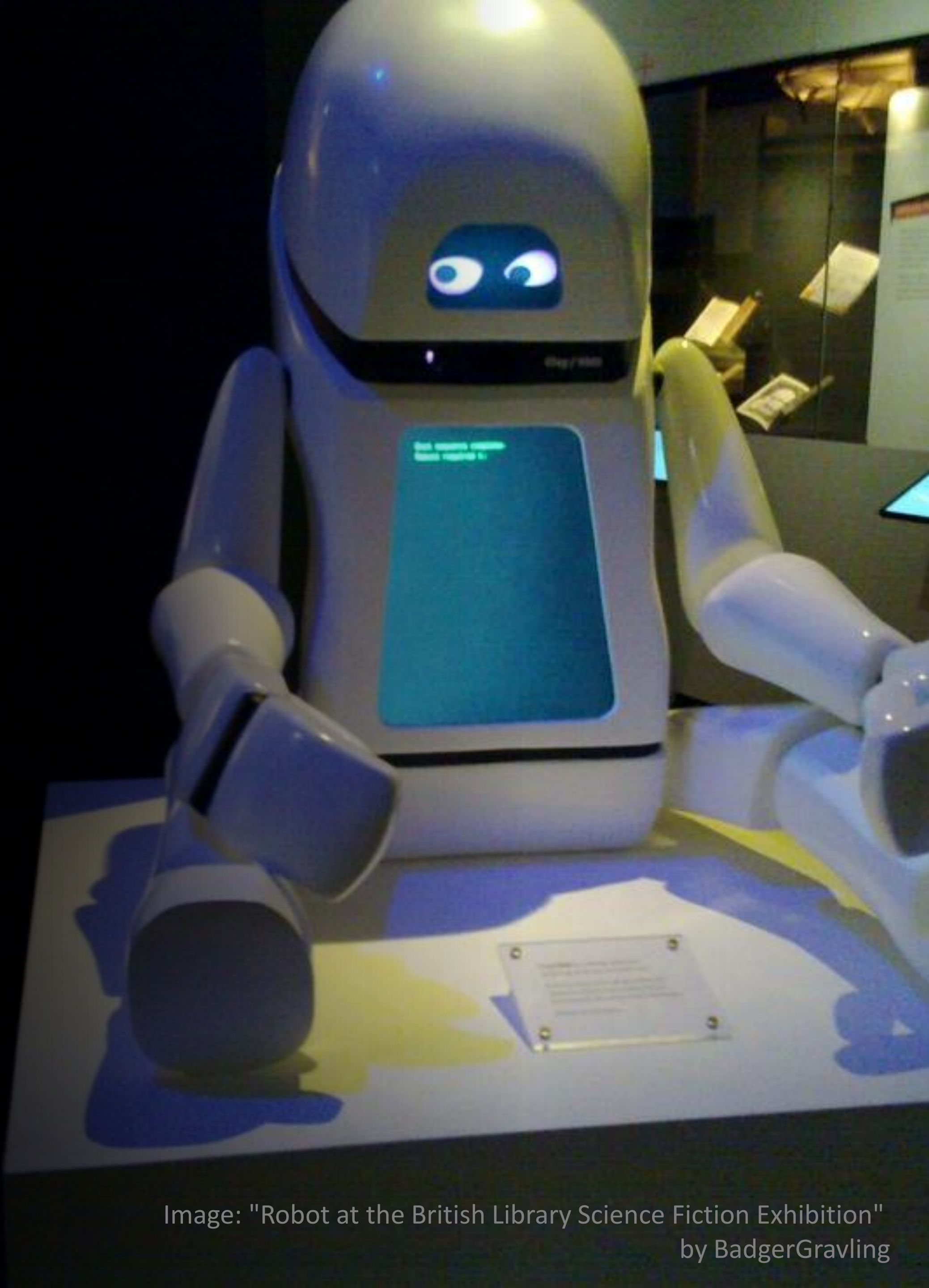
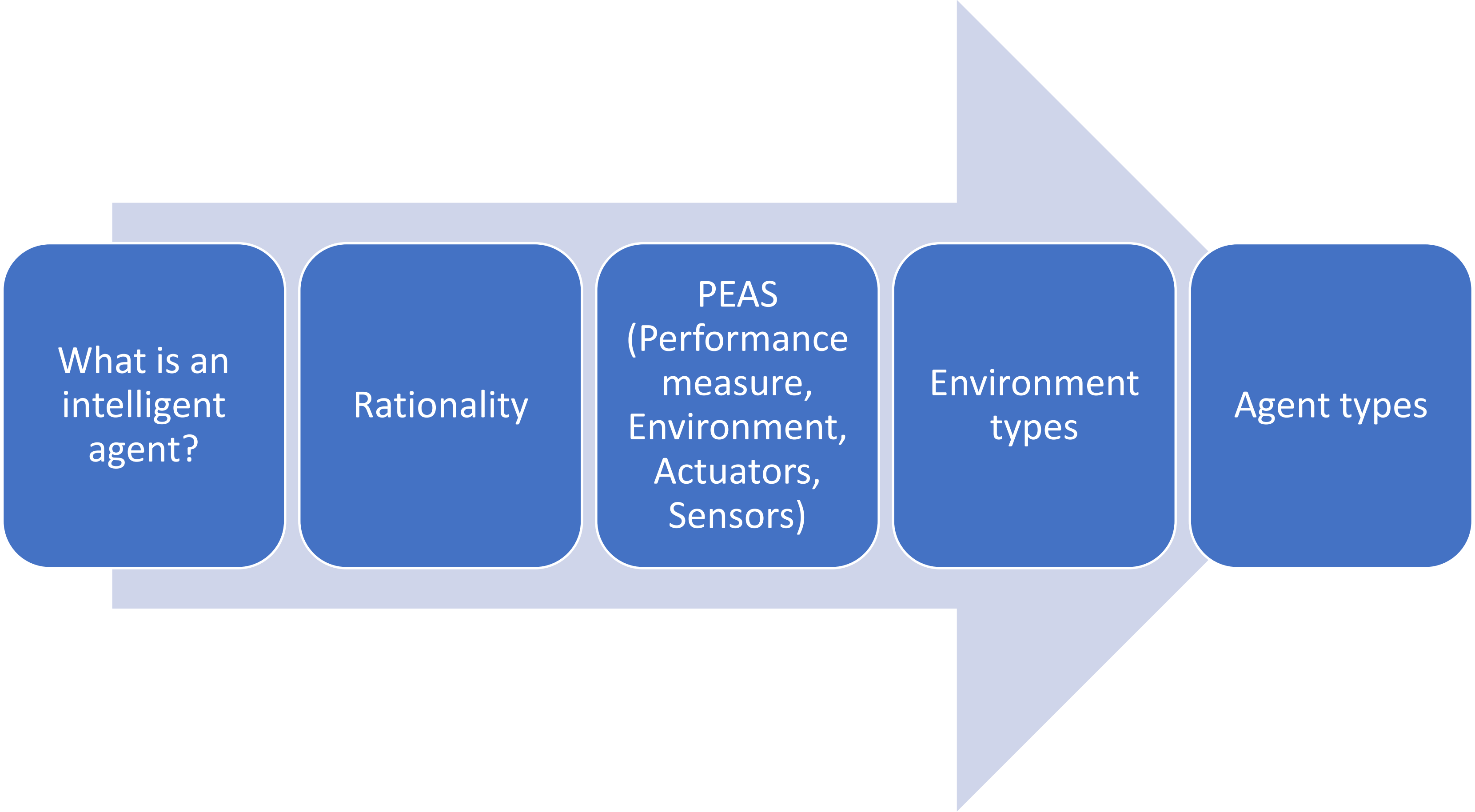


Image: "Robot at the British Library Science Fiction Exhibition" by BadgerGravling

Outline



What is an intelligent agent?

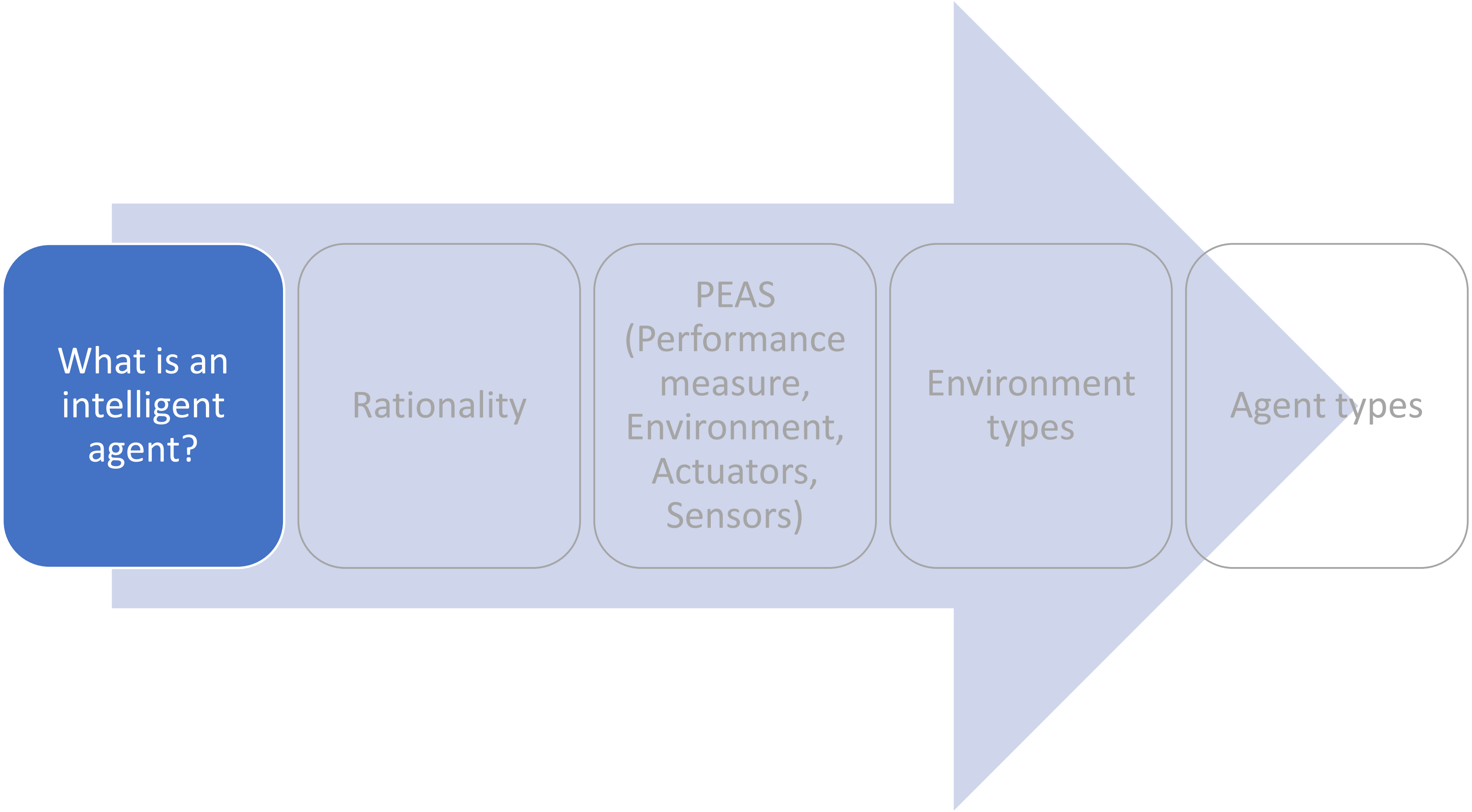
Rationality

PEAS (Performance measure, Environment, Actuators, Sensors)

Environment types

Agent types

Outline



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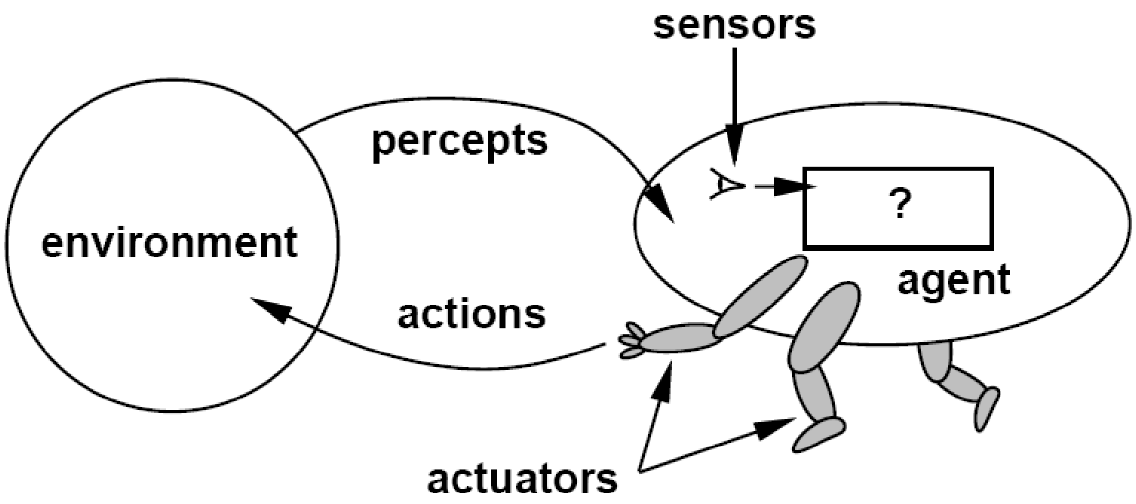
What is an Agents?

- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators.



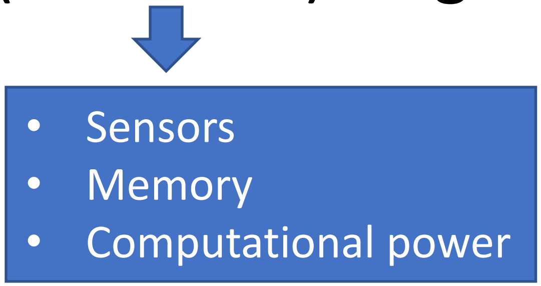
- Control theory: A **closed-loop control system** (= feedback control system) is a set of mechanical or electronic devices that automatically regulates a process variable to a desired state or set point without human interaction. The agent is called controller.
- **Softbot**: Agent is a software program that runs on a host device.

Agent Function and Agent Program

The agent function maps from the set of *percept sequences* P^* to the *set of actions* A formulated as an abstract mathematical function $f : P^* \rightarrow A$.

The agent program is the concrete implementation for a given physical system.

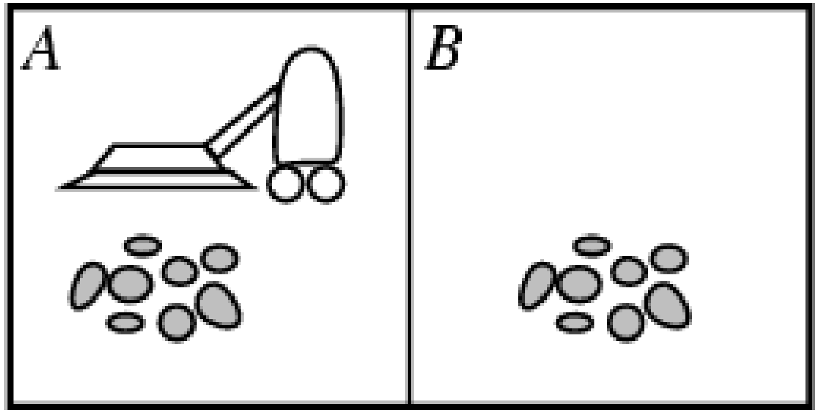
Agent = architecture (hardware) + agent program



- Sensors
- Memory
- Computational power

Example: Vacuum-cleaner World

- **Percepts:**
  Location and status,
  e.g., [A, Dirty]
- **Actions:**
  Left, Right, Suck, NoOp



Last Percept

Agent function: $f : P^* \rightarrow A$

Percept Sequence	Action
[A, Clean]	Right
[A, Dirty]	Suck
…	
[A, Clean], [B, Clean]	Left
…	
[A, Clean], [B, Clean], [A, Dirty]	Suck
…	

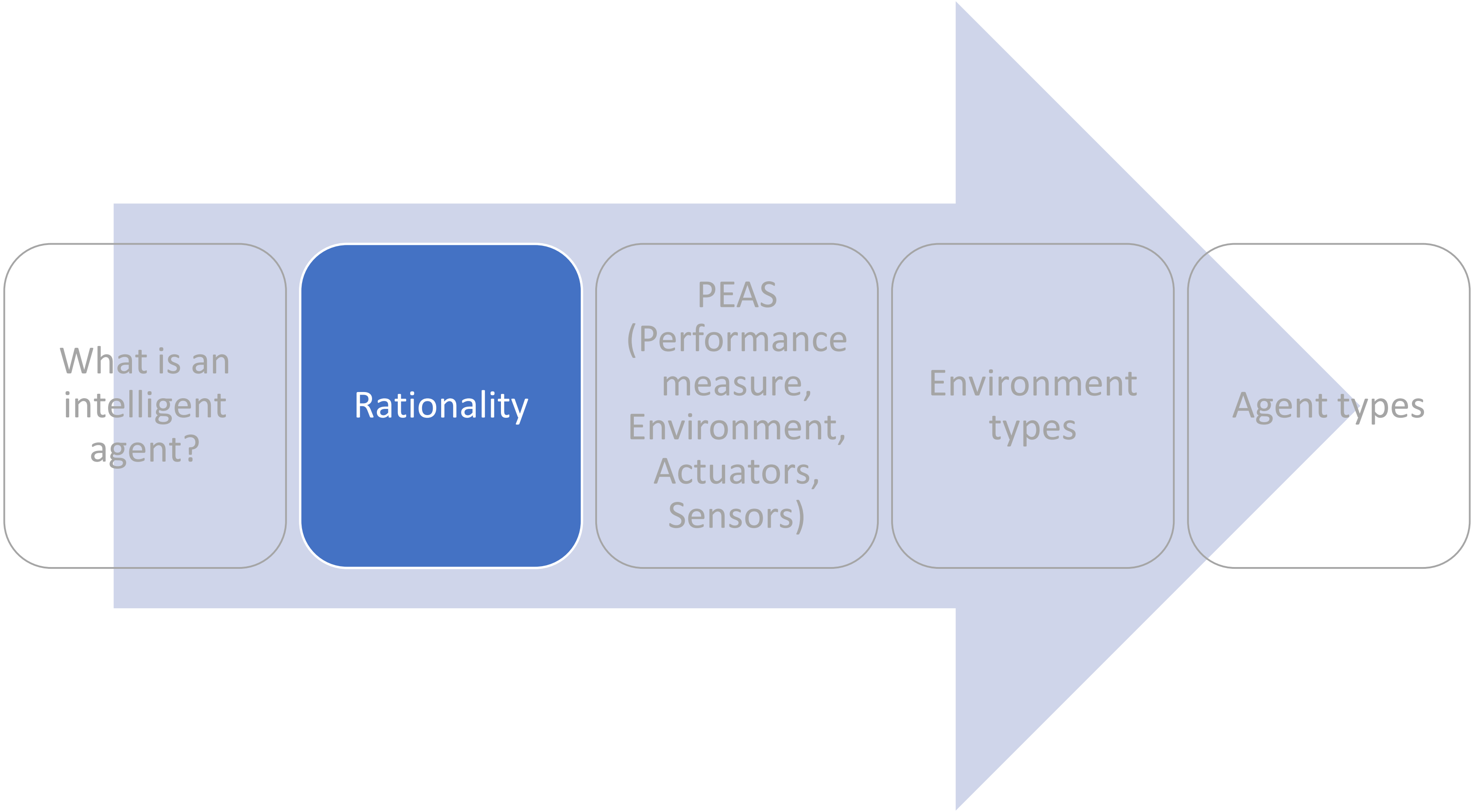
Implemented agent program:

function 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
```

This table can become infinitively large!

Outline



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Rational Agents: What is Good Behavior?

Foundation

- **Consequentialism**: Evaluate behavior by its consequences.
- **Utilitarianism**: maximize happiness and well-being

Definition of a 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 the **agent's built-in knowledge**."*

- Performance measure: An *objective* criterion for success of an agent's behavior (often called utility function).
- Expectation: Outcome averaged over all possible situations that may arise.

This means:

- **Rationality ≠ Omniscience** (rational agents can make mistakes if percepts and knowledge do not suffice to make a good decision)
- **Rationality ≠ Perfection** (rational agents maximize **expected** outcomes not actual outcomes)
- **It is rational to explore and learn** (i.e., **use percepts** to supplement prior knowledge and become autonomous)

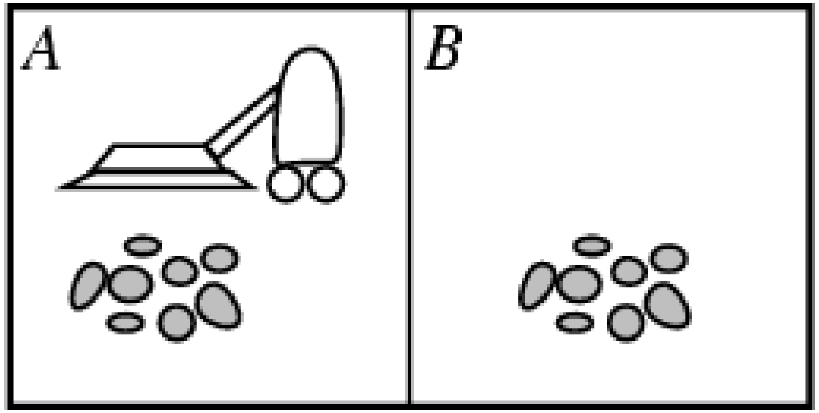
Example: Vacuum-cleaner World

- **Percepts:**

  Location and status,
  e.g., [A, Dirty]

- **Actions:**

  Left, Right, Suck, NoOp



Agent function:

Percept Sequence	Action
[A, Clean]	Right
[A, Dirty]	Suck
…	
[A, Clean], [B, Clean]	Left
…	

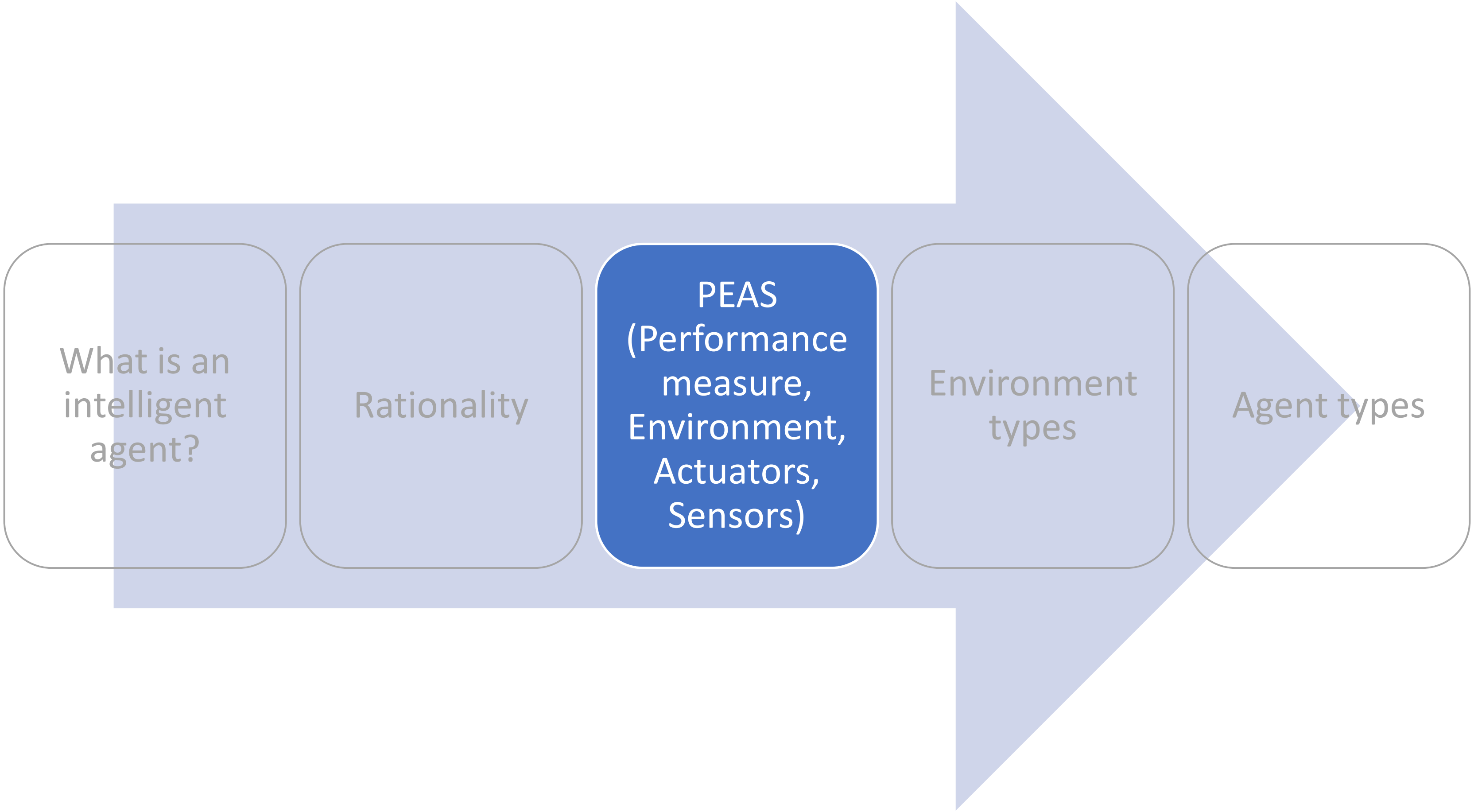
Implemented agent program:

function 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
```

What could be a performance measure?
Is this agent rational?

Outline



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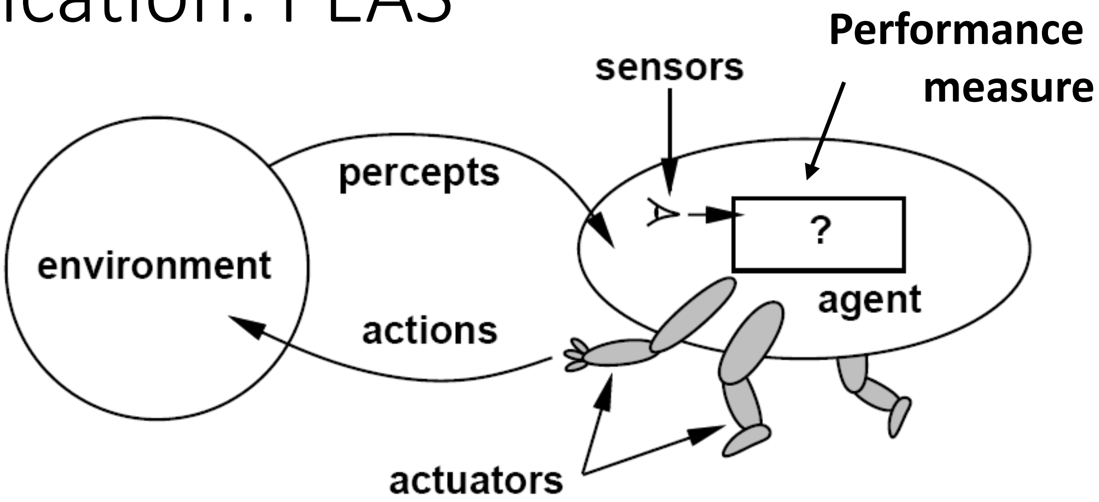
Problem Specification: PEAS



Performance measure

Defines utility and what is rational

Environment

Components and rules of how actions affect the environment.

Actuators

Defines available actions

Sensors

Defines percepts

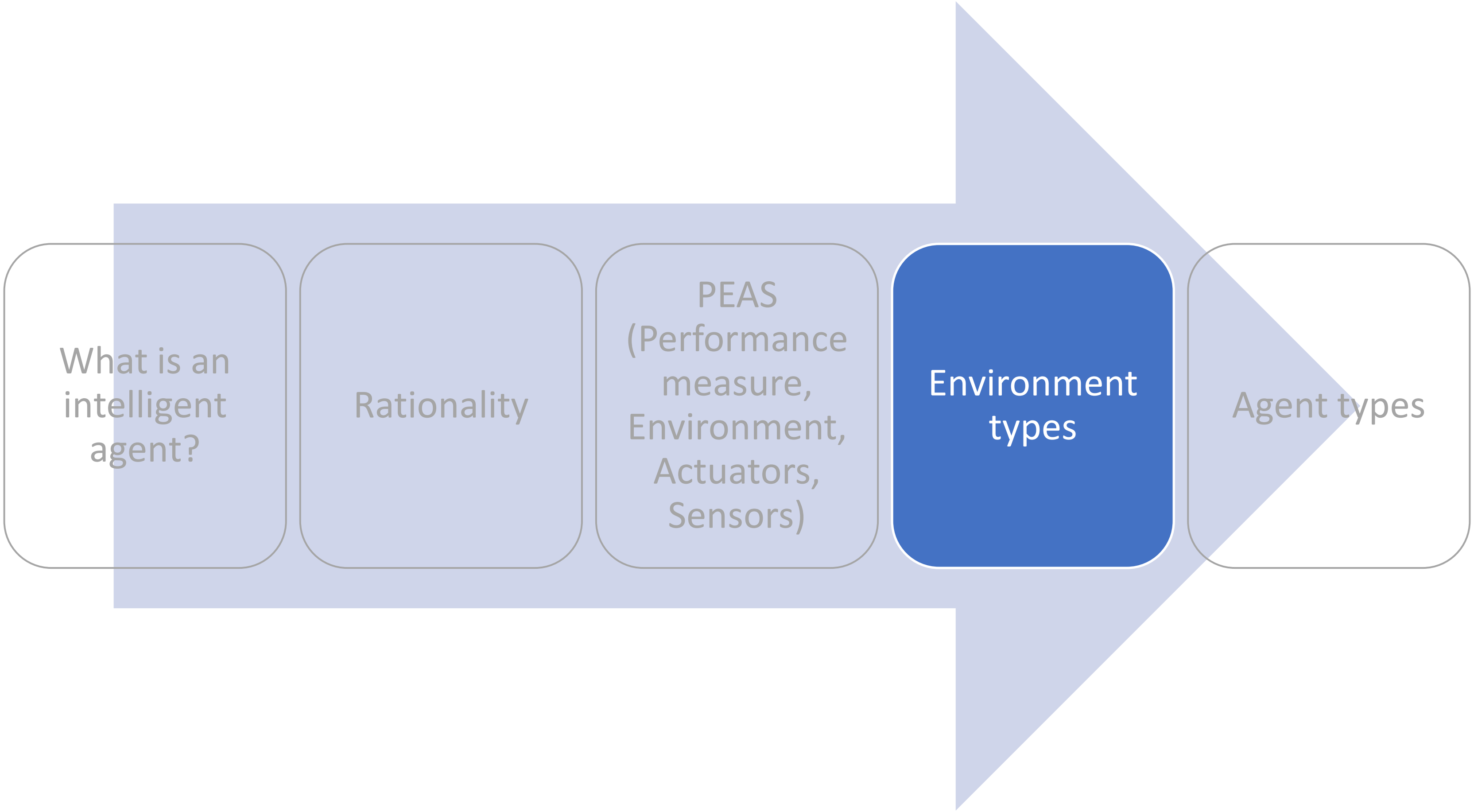
Example: Automated Taxi Driver

Performance measure	Environment	Actuators	Sensors
• Safe • fast • legal • comfortable trip • maximize profits	• Roads • other traffic • pedestrians • customers	• Steering wheel • accelerator • brake • signal • horn	• Cameras • sonar • speedometer • GPS • Odometer • engine sensors • keyboard

Example: Spam Filter

Performance measure	Environment	Actuators	Sensors
• Accuracy: Minimizing false positives, false negatives	• A user’s email account • email server	• Mark as spam • delete • etc.	• Incoming messages • other information about user’s account

Outline



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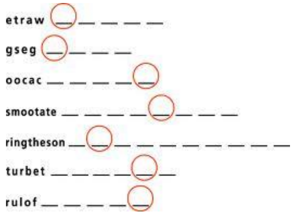
Environment Types

- **Fully observable (vs. partially observable):** The agent's sensors give it access to the complete state of the environment at each point in time.
- **Deterministic (vs. stochastic):** The next state of the environment is completely determined by the current state and the agent’s action.
  - **Strategic:** the environment mechanics are deterministic, but the next state is also determined by the actions of other agents who follow their own strategy. This makes the environment look stochastic to out agent.
- **Episodic (vs. sequential):** Episode = get precept + do action. The agent's choice of action in one episode does not affect the next episodes.

Environment Types

- **Static (vs. dynamic):** The environment is not changing while an agent is deliberating.
  - **Semidynamic:** the environment does not change while deliberating, but the agent's performance score depends on how fast it acts.
- **Discrete (vs. continuous):** The environment provides a fixed number of distinct percepts, actions, and environment states.
  - Time can also evolve in a discrete or continuous fashion.
- **Single agent (vs. multi-agent):** An agent operating by itself in an environment.
- **Known (vs. unknown):** The agent knows the rules of the environment.

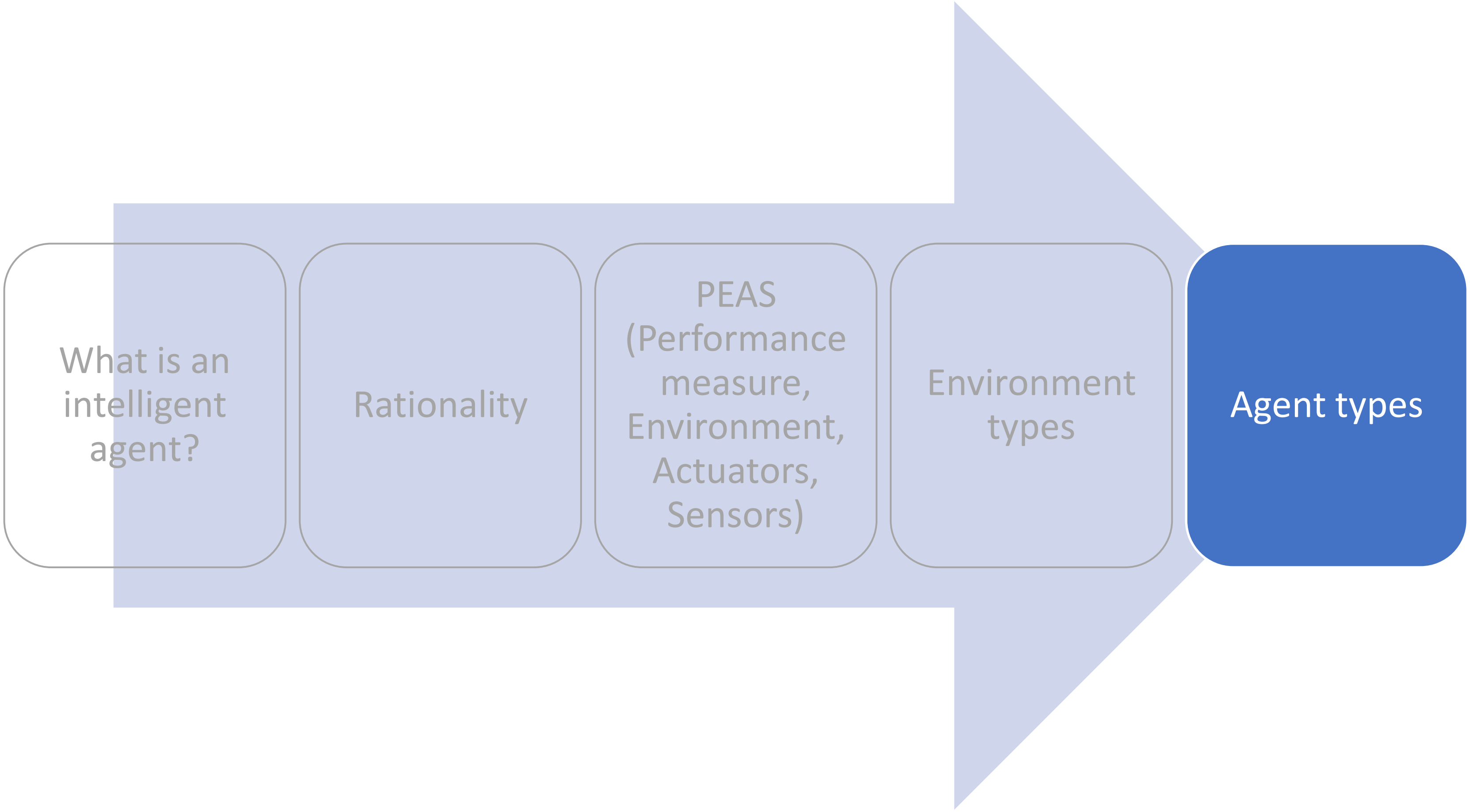
Examples of Different Environments



	Word jumble solver	Chess with a clock	Scrabble	Taxi driving
Observable	Fully	Fully	Partially	Partially
Deterministic	Deterministic	Strategic	Stochastic +Strategic	Stochastic
Episodic	Episodic	Sequential	Sequential	Sequential
Static	Static	Semidynamic	Static	Dynamic
Discrete	Discrete	Discrete	Discrete	Continuous
Single agent	Single	Multi	Multi	Multi

Actions have long-term effects.

Outline



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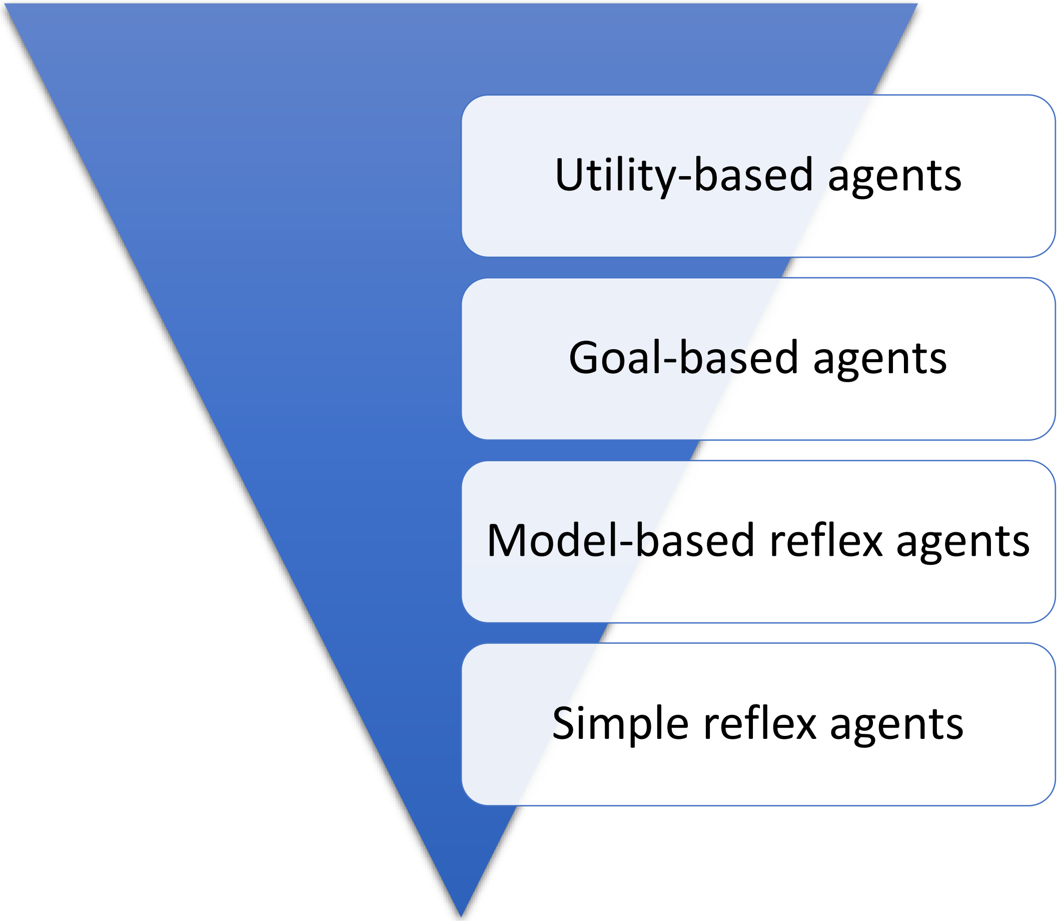
Hierarchy of Agent Types



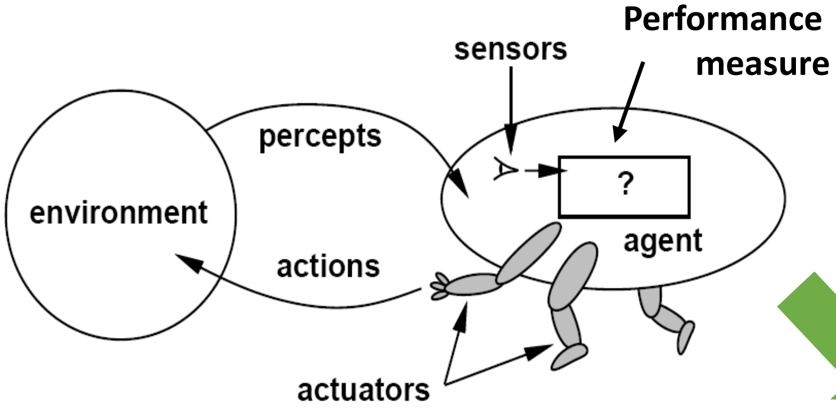
Utility-based agents

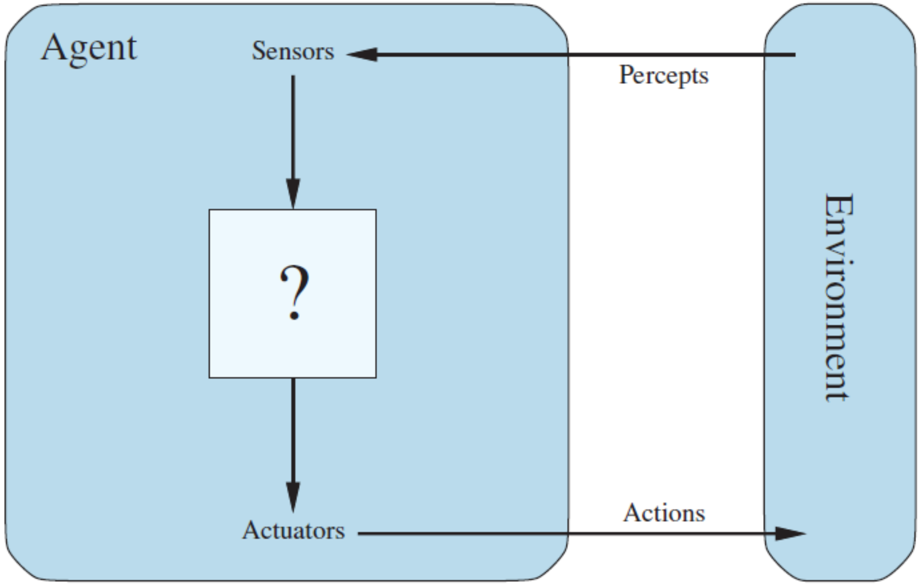
Goal-based agents

Model-based reflex agents

Simple reflex agents

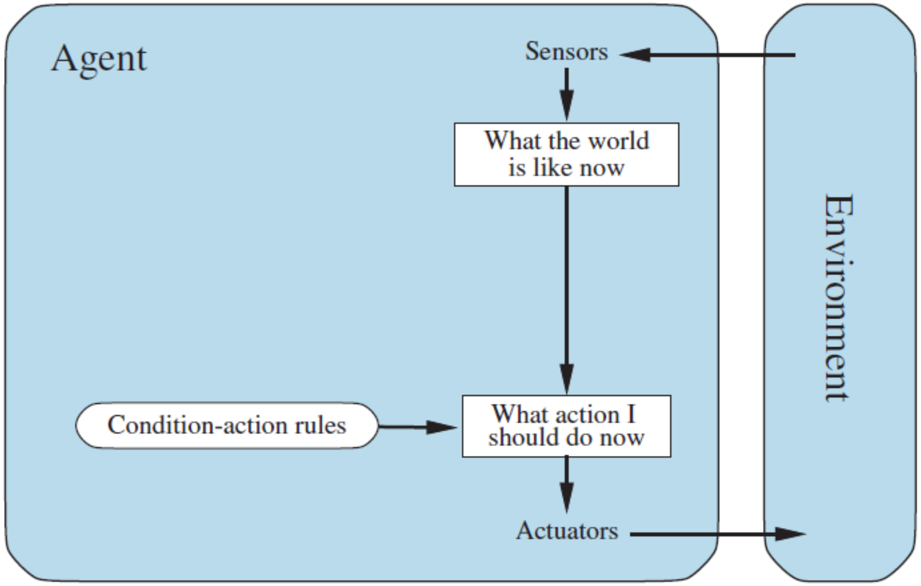
Structure of an Agent





Simple Reflex Agent

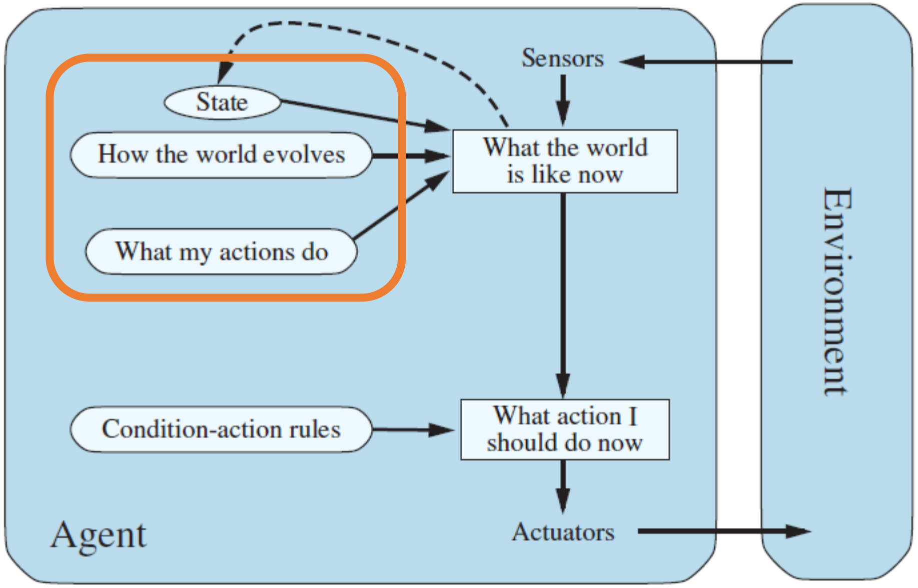
- **Rules** select action only **based on current percept.** This is typically very fast!
- The agent does not know about the performance measure, but well-designed rules can lead to good performance.
- It has no memory and thus ignores all past percepts.



Example: A simple vacuum cleaner that uses rules based on its current sensor input.

Model-based Reflex Agent

- Maintains an **internal state** (memory) to keeps track of aspects of the environment that cannot be currently observed.
- There is now more information for the rules to make better decisions.

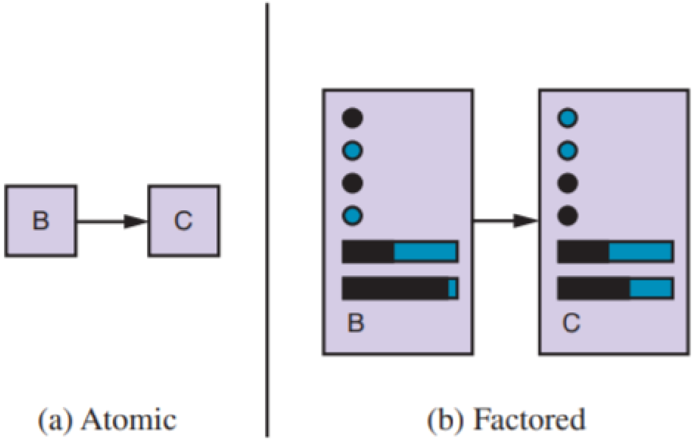


Example: A vacuum cleaner that remembers were it has already cleaned.

State Representation

States help to keep track of the environment. The representation can be

- **Atomic**: Just a label for a black box. E.g., A, B
- **Factored**: A vector of attribute values. E.g., [location = left, status = clean, temperature = 75 deg. F]



(a) Atomic

(b) Factored

State Space: The set of all possible states.

Old-school vs. Smart Thermostat

Old-school thermostat

Percepts

States

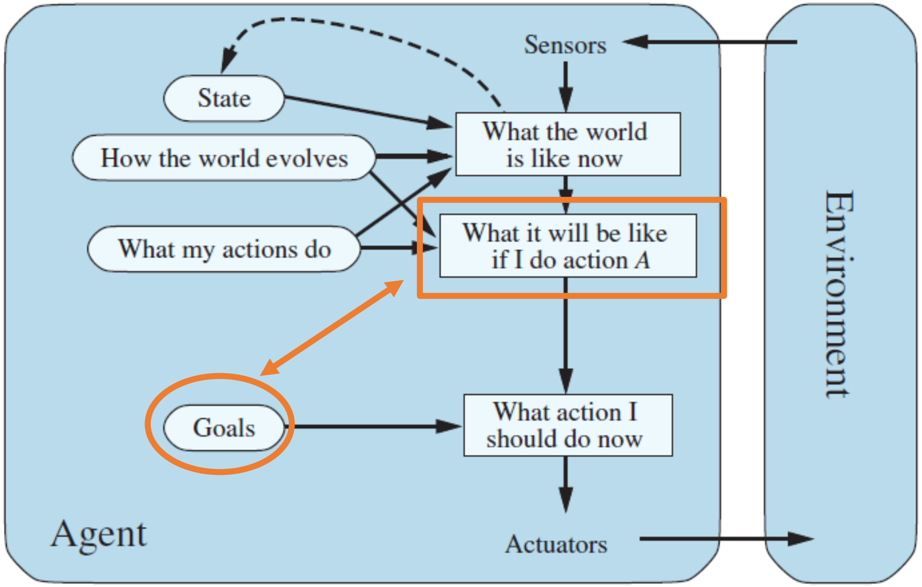
Smart thermostat

Percepts

States

Goal-based Agent

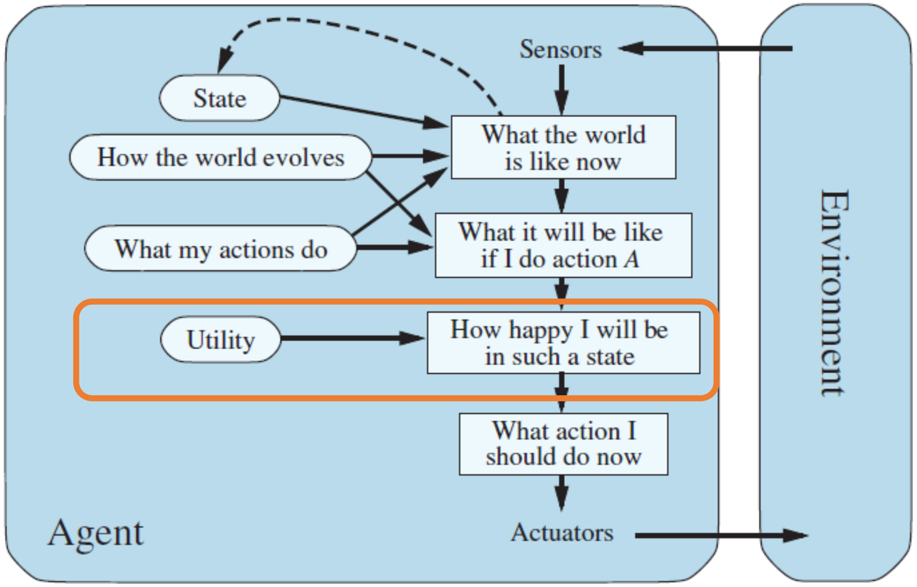
- The agent has the task to reach a defined **goal state**.
- The agent needs to move towards the goal. It can use **search algorithms** to plan actions that lead to the goal.
- The performance measure is typically the cost to reach the goal.


Sensors
State
What the world is like now
How the world evolves
What it will be like if I do action *A*
What my actions do
Goals
What action I should do now
Agent
Actuators
Environment

Example: Solving a puzzle. What action gets me closer to the solution?

Utility-based Agent

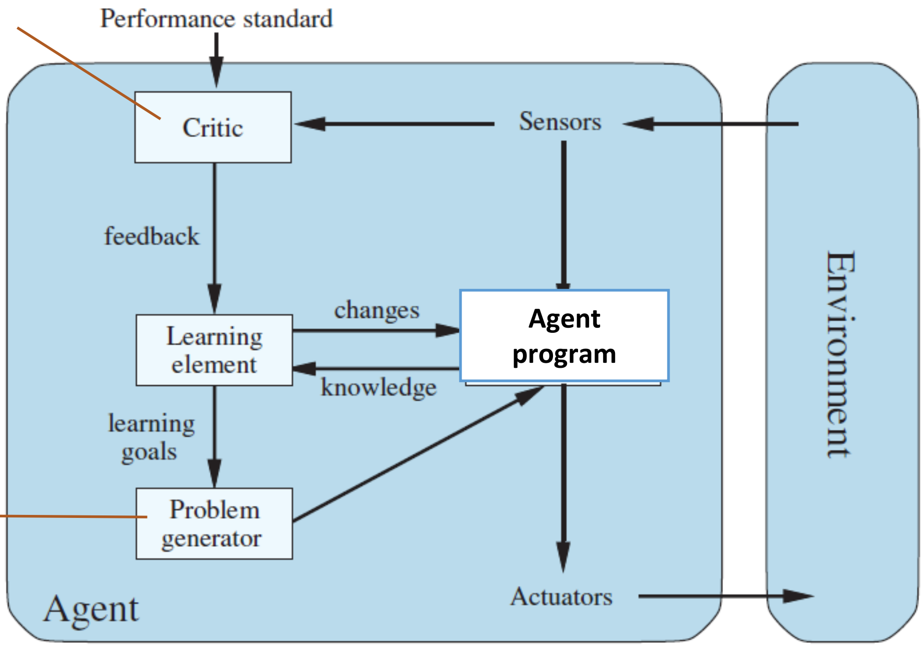
- The agent uses a utility function to evaluate the **desirability of each different states.**
- Performance measure: Choose actions to maximize expected utility over time (i.e., stay in desirable states).


Sensors
State
What the world is like now
How the world evolves
What it will be like if I do action *A*
What my actions do
Utility
How happy I will be in such a state
What action I should do now
Agent
Actuators
Environment

Example: An autonomous Mars rover prefers states where its battery is not critically low.

Agents that Learn

The **learning element** modifies the agent program (reflex-based, goal-based, or utility-based) to improve its performance.



How is the agent currently performing?

Exploration

Smart Thermostat

Change temperature when you are too cold/warm.

Smart thermostat

Percepts

- Temp: deg. F
- Outside temp.
- Weather report
- Energy curtailment
- Someone walking by
- Someone changes temp.
- Day & time
- …

States

Factored states

- Estimated time to cool the house
- Someone home?
- How long till someone is coming home?
- A/C: on, off

Reflex Agent?

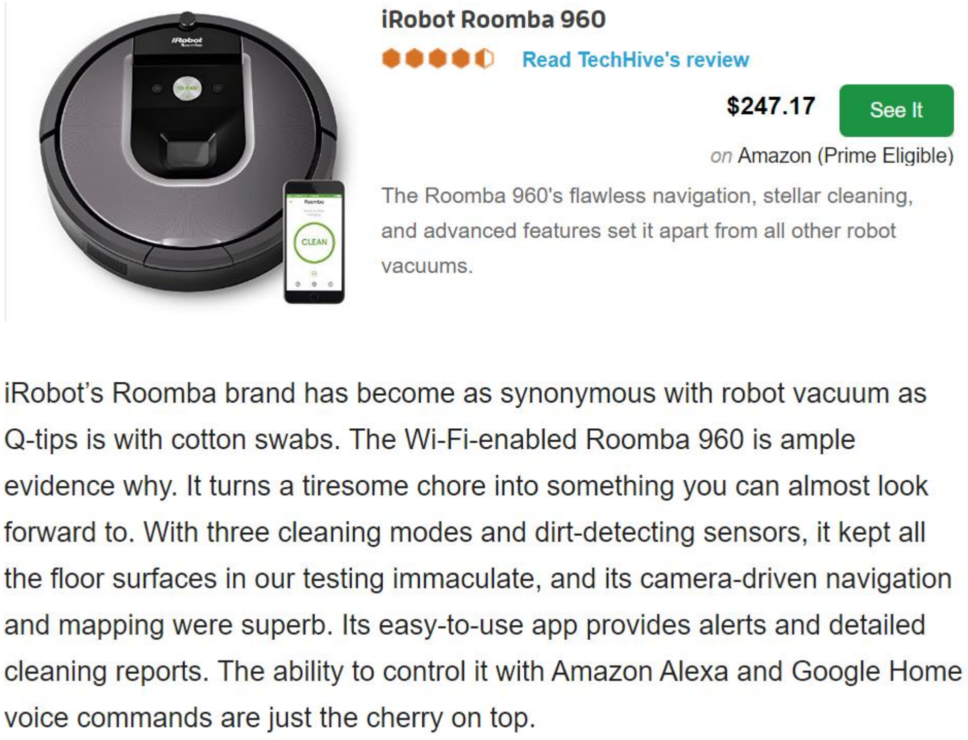
Goal-based?

Utility-based?

What Type of Intelligent Agent is this?

Features are:

- Control via App
- Cleaning Modes
- Navigation
- Mapping
- Boundary blockers



iRobot Roomba 960

●●●●◐ Read TechHive's review

$247.17 See It

on Amazon (Prime Eligible)

The Roomba 960's flawless navigation, stellar cleaning, and advanced features set it apart from all other robot vacuums.

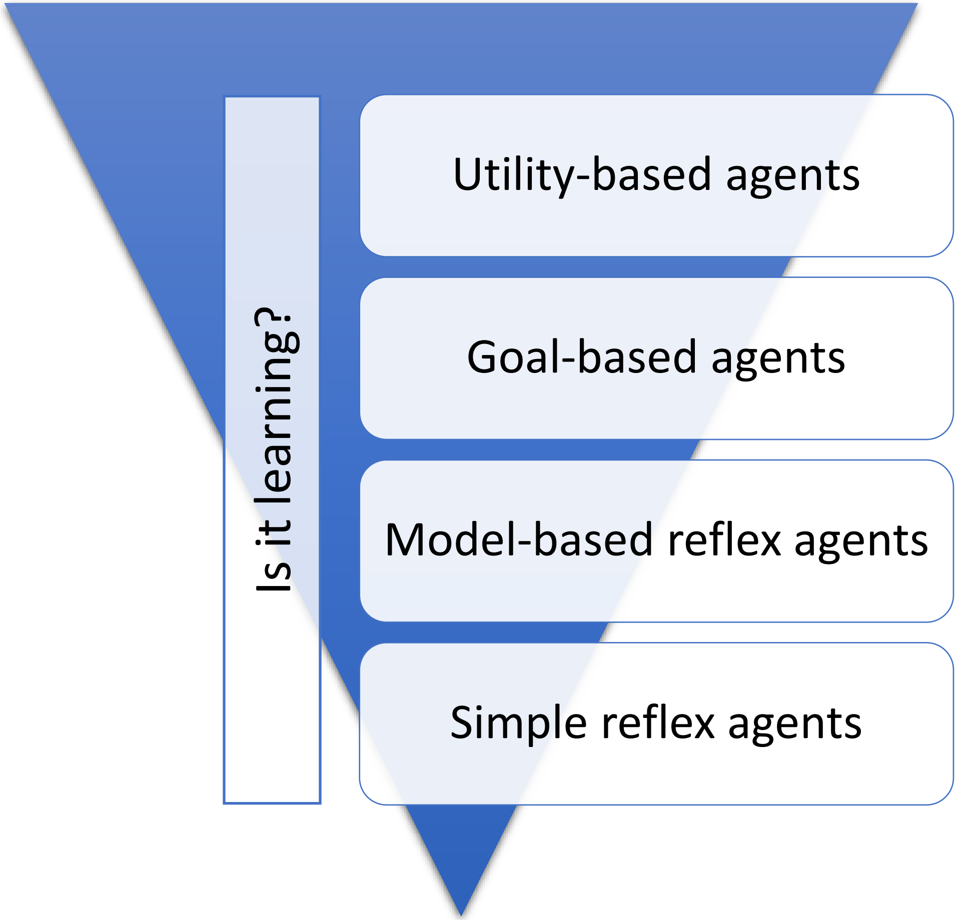
iRobot's Roomba brand has become as synonymous with robot vacuum as Q-tips is with cotton swabs. The Wi-Fi-enabled Roomba 960 is ample evidence why. It turns a tiresome chore into something you can almost look forward to. With three cleaning modes and dirt-detecting sensors, it kept all the floor surfaces in our testing immaculate, and its camera-driven navigation and mapping were superb. Its easy-to-use app provides alerts and detailed cleaning reports. The ability to control it with Amazon Alexa and Google Home voice commands are just the cherry on top.

Source: https://www.techhive.com/article/3269782/best-robot-vacuum-cleaners.html

PEAS Description of a Modern Robot Vacuum

Performance measure	Environment	Actuators	Sensors

What Type of Intelligent Agent is it?



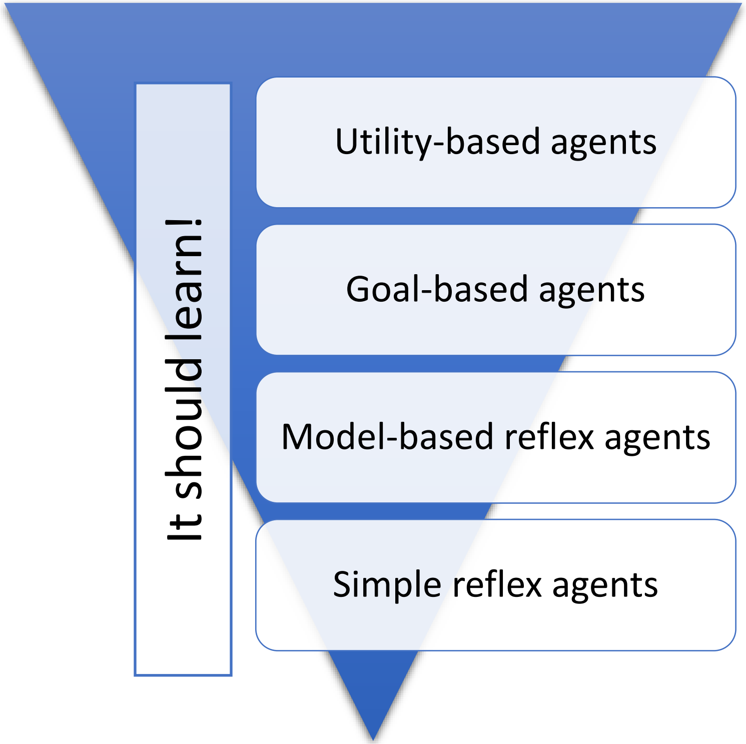
Does it collect utility over time? How would the utility for each state be defined?

Does it have a goal state?

Does it store state information. How would they be defined (atomic/factored)?

Does it use simple reflexes?

Intelligent Systems as Sets of Agents: Self-driving Car



It should learn!

Utility-based agents

Goal-based agents

Model-based reflex agents

Simple reflex agents

Make sure the passenger has a pleasant drive (not too much sudden breaking = utility)

Plan the route to the destination.

Remember where every other car is and calculate where they will be in the next few seconds.

React to unforeseen issues like a child running in front of the car quickly.

Conclusion

Intelligent agents inspire the research areas of modern AI

Search for a goal (e.g., navigation).

Optimize functions (e.g., utility).

Stay within given **constraints**

(constraint satisfaction problem; e.g., reach the goal without running out of power)

Deal with **uncertainty** (e.g., current traffic on the road).

Learn a good agent program from data and improve over time (machine learning).

Sensing
(e.g, natural language processing, vision)