Intelligent Agents

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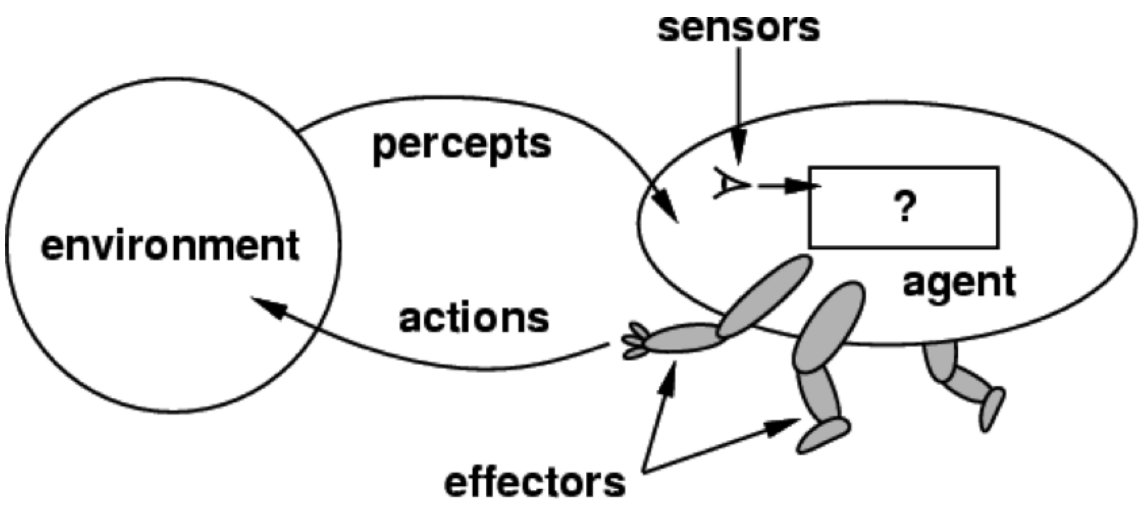
Agents and Environments

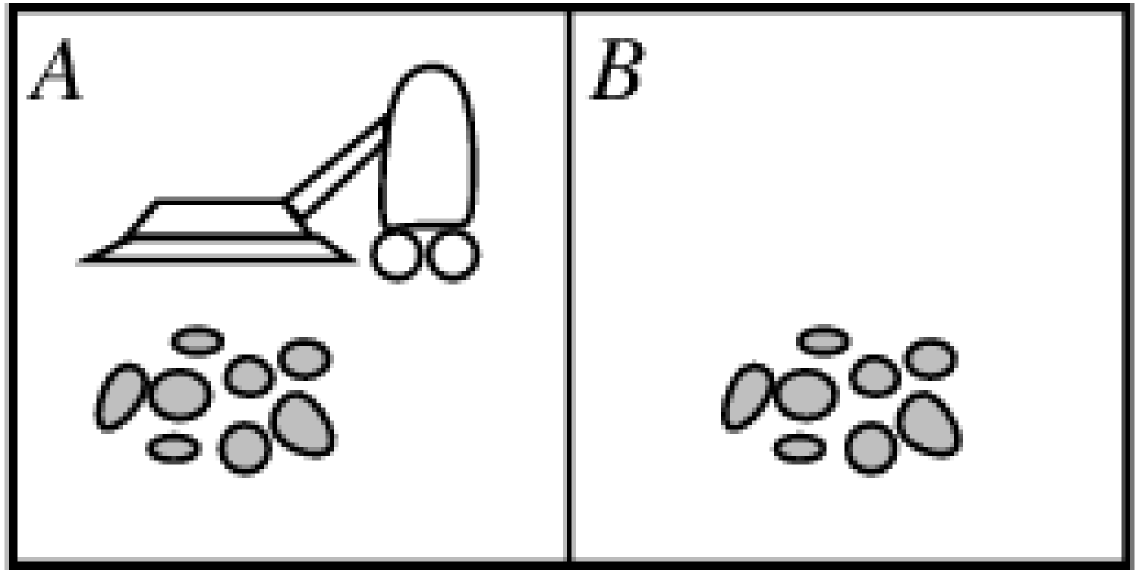


- Agents include humans, robots, softbots, thermostats, etc.
- The agent function maps from percept histories to actions:

$$f : \mathcal{P}^* \rightarrow \mathcal{A}$$

- The agent program runs on the physical architecture to produce f

Vacuum Cleaner World



- Percepts: location and contents, e.g., $[A, Dirty]$
- Actions: $Left$, $Right$, $Suck$, $NoOp$

Vacuum Cleaner Agent

Table

Percept sequence	Action
$[A, Clean]$	$Right$
$[A, Dirty]$	$Suck$
$[B, Clean]$	$Left$
$[B, Dirty]$	$Suck$
$[A, Clean], [A, Clean]$	$Right$
$[A, Clean], [A, Dirty]$	$Suck$
⋮	⋮

Function

Input: location, status
Output: action

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

- 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
  $\rightarrow$ percepts may not supply all relevant information

- Rational $\neq$ clairvoyant
  $\rightarrow$ action outcomes may not be as expected

- Hence, rational $\neq$ successful

- Rational $\implies$ exploration, learning, autonomy

intelligent agent

Intelligent Agent

- Definition:

  An intelligent agent perceives its environment via sensors and acts rationally upon that environment with its effectors.

- A **discrete** agent receives percepts one at a time, and maps this percept sequence to a sequence of discrete actions.

- Properties
  - autonomous
  - reactive to the environment
  - pro-active (goal-directed)
  - interacts with other agents via the environment

Sensors/Percepts and Effectors/Actions

- For example: humans
  - **Sensors:** Eyes (vision), ears (hearing), skin (touch), tongue (gustation), nose (olfaction), neuromuscular system (proprioception)
  - **Percepts:**
    - At the lowest level: electrical signals from these sensors
    - After preprocessing: objects in the visual field (location, textures, colors, ...), auditory streams (pitch, loudness, direction), ...
  - **Effectors:** limbs, digits, eyes, tongue, ...
  - **Actions:** lift a finger, turn left, walk, run, carry an object, ...
- Percepts and actions need to be carefully defined,
possibly at different levels of abstraction

Example: Self-Driving Car

- Percepts: Video, sonar, speedometer, odometer, engine sensors, keyboard input, microphone, GPS, ...

- Actions: Steer, accelerate, brake, horn, speak/display, ...

- 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

- An ideal rational agent should, for each possible percept sequence, do whatever actions will maximize its expected performance measure based on
  - percept sequence
  - built-in and acquired knowledge

- Rationality includes information gathering, not ”rational ignorance”
  (If you don’t know something, find out!)

- Need a performance measure to say how well a task has been achieved

- Types of performance measures
  - false alarm (false positive) rate
  - false dismissal (false negative) rate
  - speed
  - resources required
  - impact on environment
  - etc.

Autonomy

- A system is autonomous to the extent that its own behavior is determined by its own experience
- Therefore, a system is not autonomous if it is guided by its designer according to a priori decisions
- To survive, agents must have
  - enough built-in knowledge to survive
  - ability to learn

agent types

Agent Types

- Table-driven agents
  use a percept sequence/action table in memory to find the next action. They are implemented by a (large) lookup table.
- Simple reflex agents
  are based on condition-action rules, implemented with an appropriate production system. They are stateless devices which do not have memory of past world states.
- Agents with memory
  have internal state, which is used to keep track of past states of the world.
- Agents with goals
  are agents that, in addition to state information, have goal information that describes desirable situations. Agents of this kind take future events into consideration.
- Utility-based agents
  base their decisions on classic axiomatic utility theory in order to act rationally.

Table-Driven Agents

- Table lookup of percept-action pairs mapping from every possible perceived state to the optimal action for that state

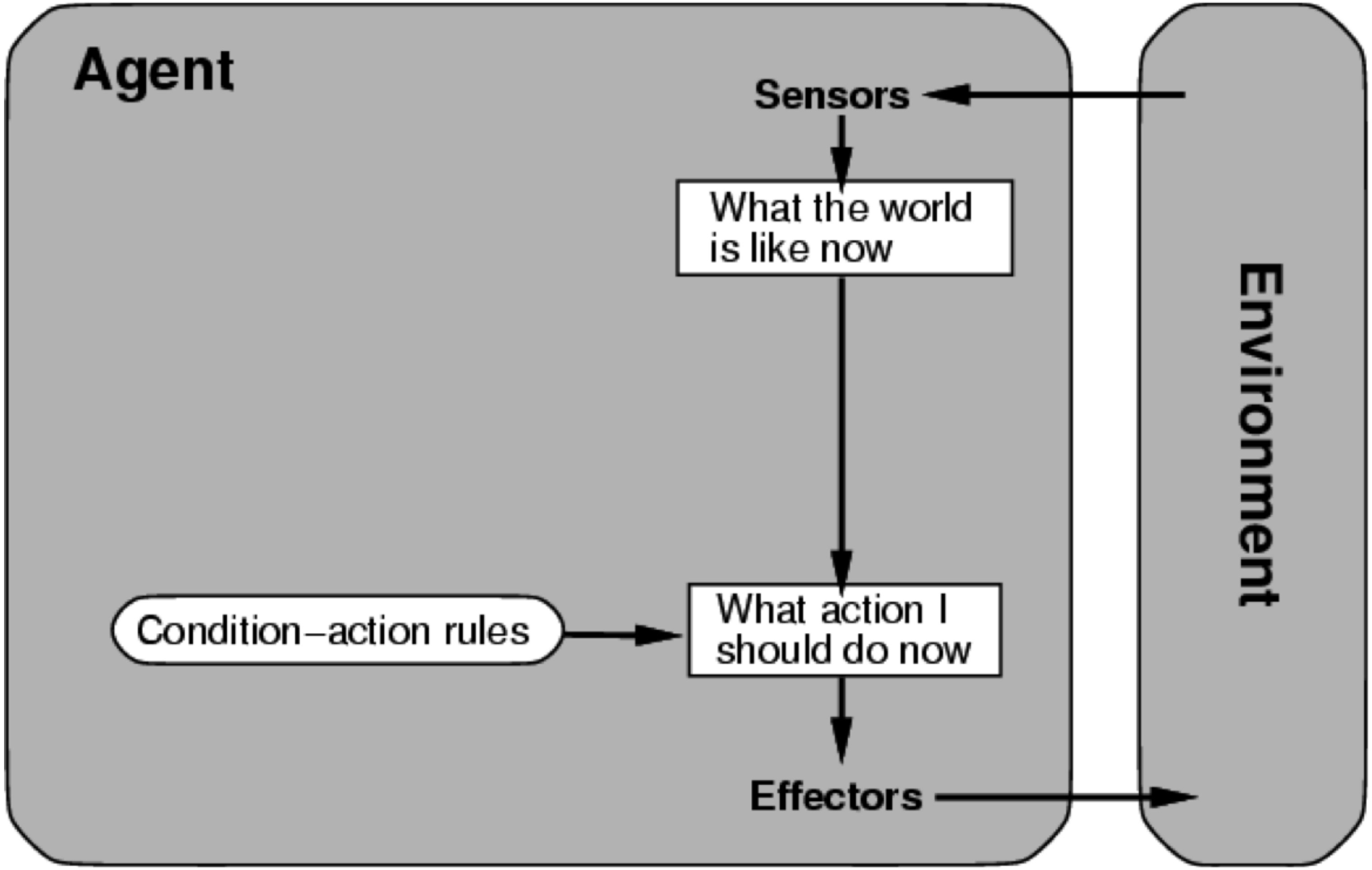
- Problems
  - too big to generate and to store (Chess has about 10^{120} states, for example)
  - no knowledge of non-perceptual parts of the current state
  - not adaptive to changes in the environment; requires entire table to be updated if changes occur
  - looping: can't make actions conditional on previous actions/states

Simple Reflex Agents

- **Rule-based reasoning** to map from percepts to optimal action; each rule handles a collection of perceived states

- Problems
  - still usually too big to generate and to store
  - still no knowledge of non-perceptual parts of state
  - still not adaptive to changes in the environment; requires collection of rules to be updated if changes occur
  - still can't make actions conditional on previous state

Architecture of Table-Driven/Reflex Agent



Agents with Memory

- Encode ”internal state” of world to remember past contained in earlier percepts
- Needed because sensors do not usually give the entire state of the world at each input, so perception of the environment is captured over time.
- ”State” is used to encode different ”world states” that generate the same immediate percept
- Requires ability to represent change in the world; one possibility is to represent just the latest state, but then can’t reason about hypothetical courses of action
- Example: Rodney Brooks’s Subsumption Architecture

Brooks' Subsumption Architecture

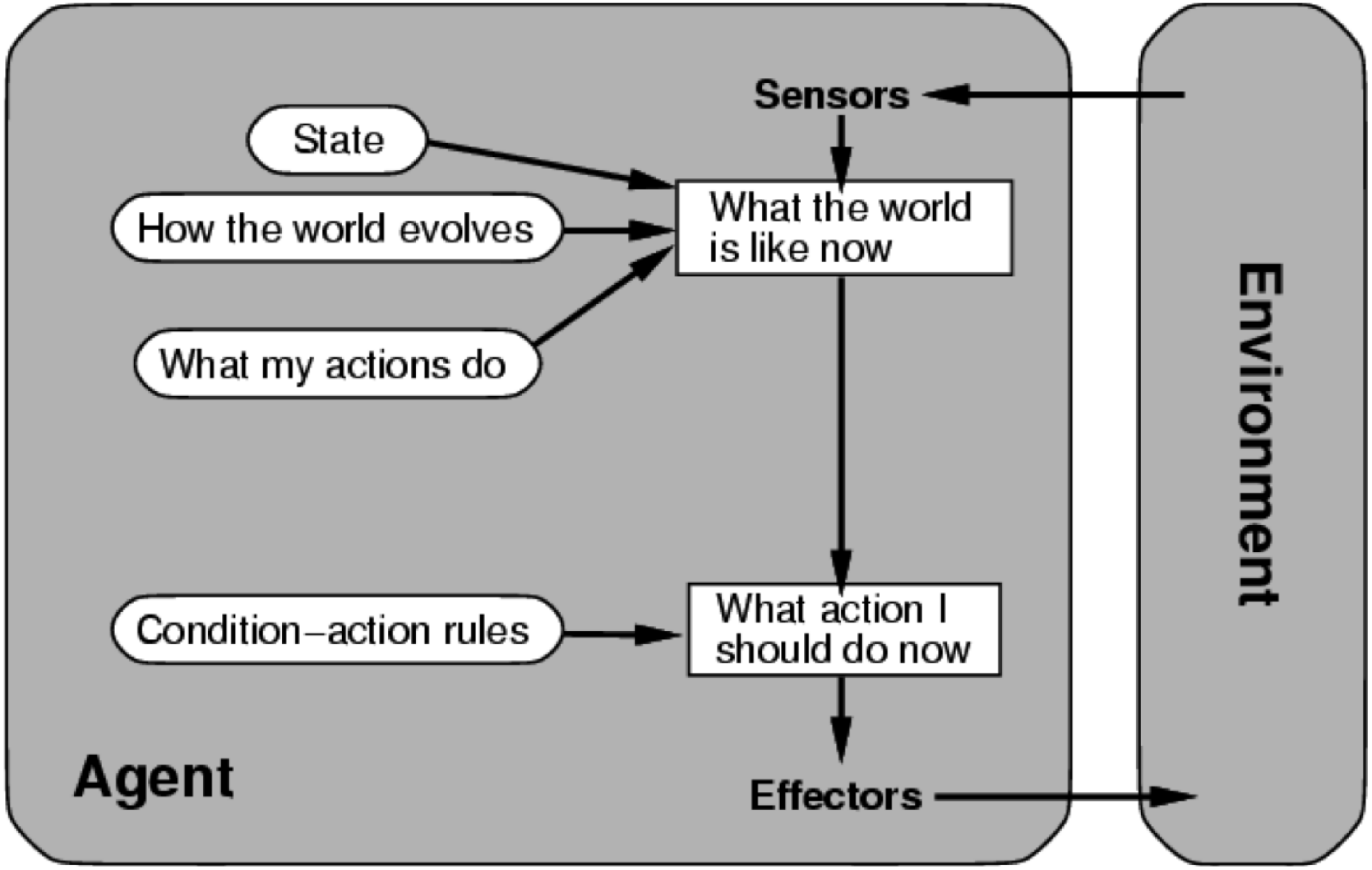
- Main idea: build complex, intelligent robots by decomposing behaviors into a hierarchy of skills, each completely defining a complete percept-action cycle for one very specific task

- Examples:
  - avoiding contact
  - wandering
  - exploring
  - recognizing doorways

- Each behavior is modeled by a finite-state machine with a few states

- Behaviors are loosely coupled, asynchronous interactions

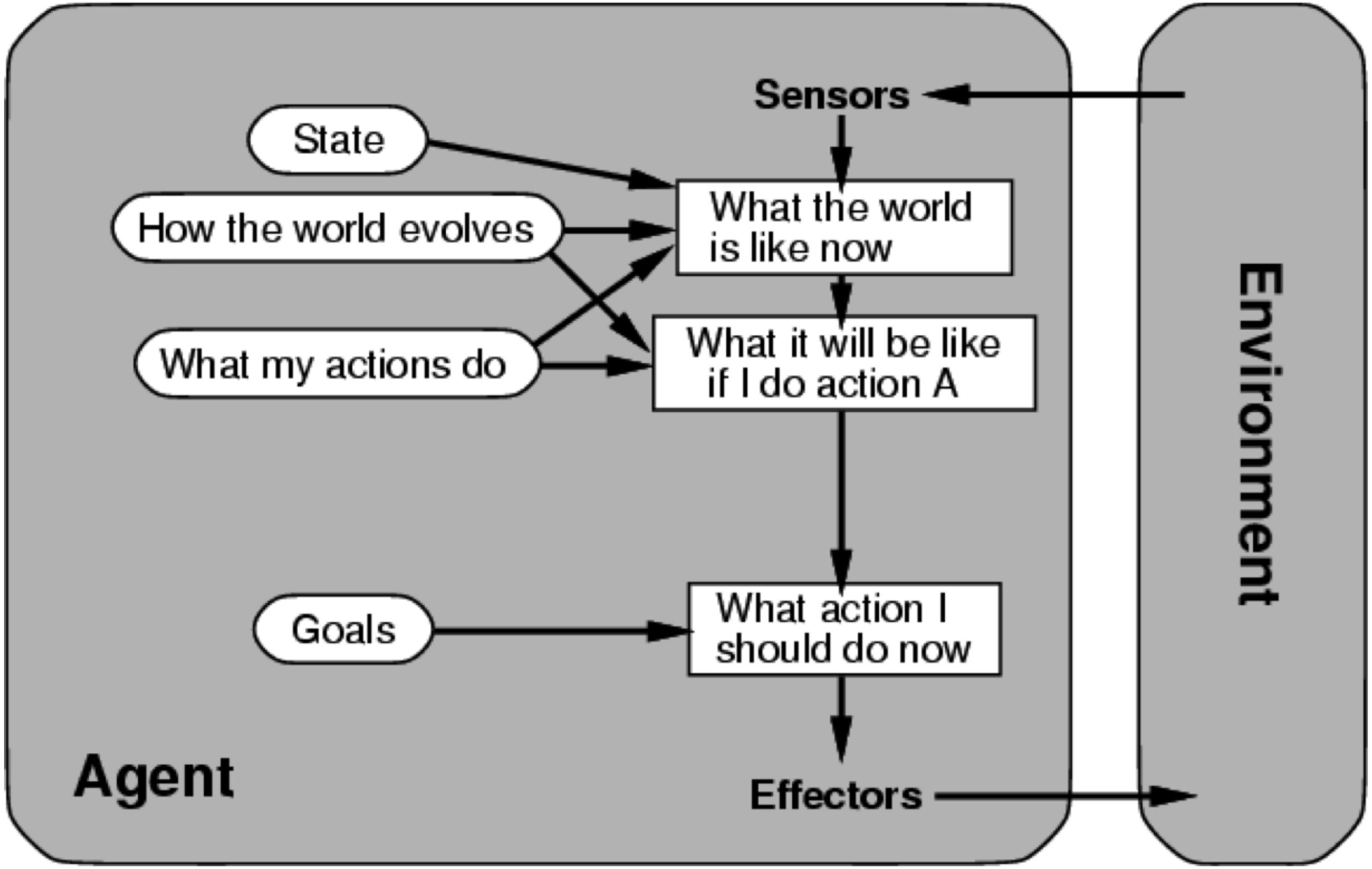
Architecture of Agent with Memory



Goal-Based Agent

- Choose actions so as to achieve a (given or computed) goal.
- A goal is a description of a desirable situation.
- Keeping track of the current state is often not enough:
  need to add goals to decide which situations are good
- Deliberative instead of reactive.
- May have to consider long sequences of possible actions before deciding if goal is achieved
  (involves consideration of the future, *"what will happen if I do...?"*)

Architecture of Goal-Based Agent



Utility-Based Agent

- When there are multiple possible alternatives, how to decide which one is best?

- A goal specifies a crude distinction between a happy and unhappy state, but often need a more general performance measure that describes ”degree of happiness.”

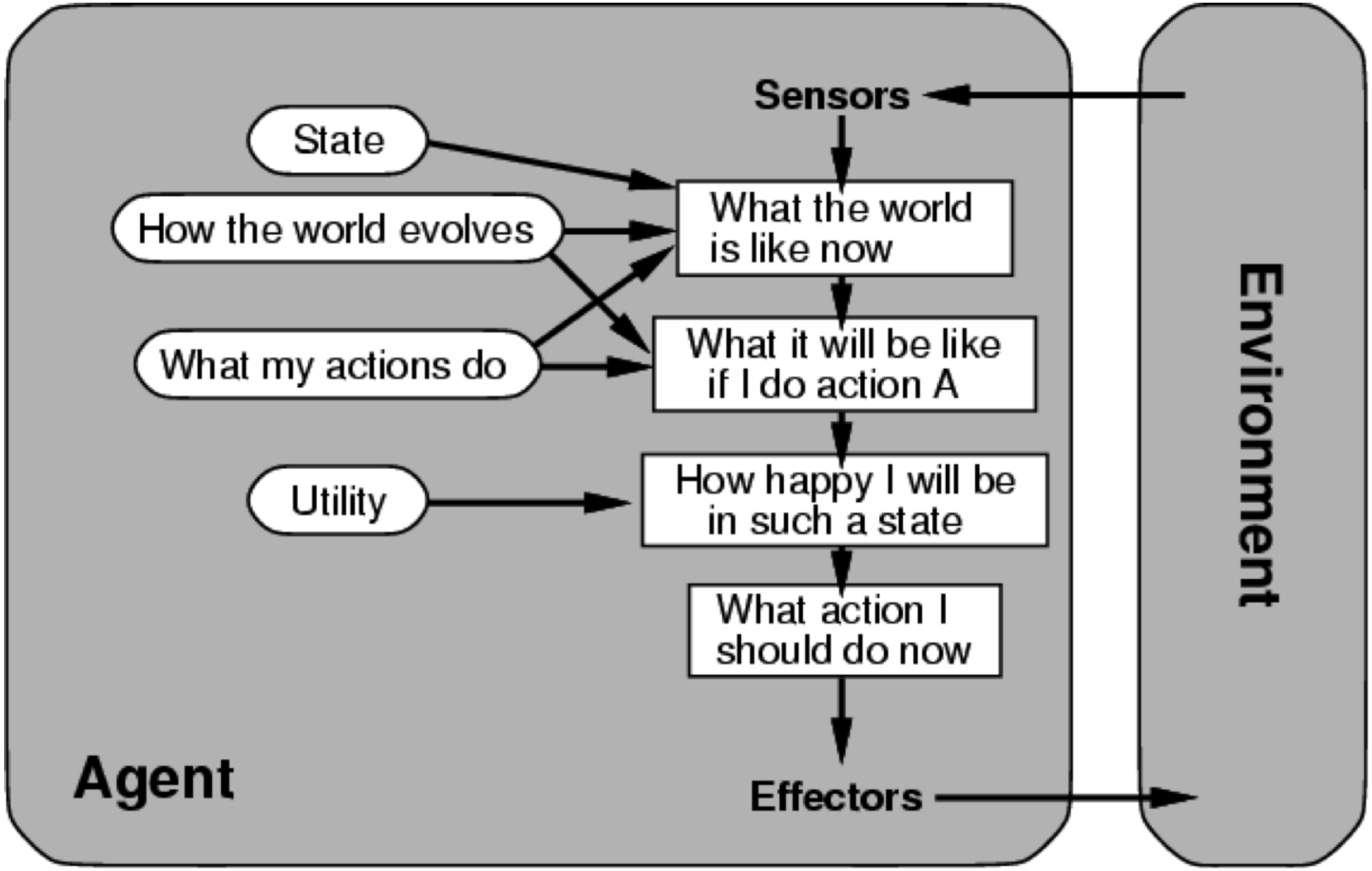
- Utility function

  $$U\text{: State} \rightarrow \text{Real Numbers}$$

  indicating a measure of success or happiness when at a given state.

- Allows decisions comparing choice between conflicting goals, and choice between likelihood of success and importance of goal (if achievement is uncertain).

Architecture of Utility-Based Agent



environment

Properties of Environments

- Accessible/Inaccessible.
  - if an agent's sensors give it access to the complete state of the environment needed to choose an action, the environment is accessible.
  - such environments are convenient, since the agent is freed from the task of keeping track of the changes in the environment.
- Deterministic/Nondeterministic
  - an environment is deterministic if the next state of the environment is completely determined by the current state of the environment and the action of the agent.
  - in an accessible and deterministic environment, the agent need not deal with uncertainty.
- Episodic/Sequential
  - an episodic environment means that subsequent episodes do not depend on what actions occurred in previous episodes.
  - such environments do not require the agent to plan ahead.

Properties of Environments

- Static/Dynamic
  - a static environment does not change while the agent is thinking.
  - the passage of time as an agent deliberates is irrelevant.
  - the agent doesn't need to observe the world during deliberation.

- Discrete/Continuous
  - if the number of distinct percepts and actions is limited, the environment is discrete, otherwise it is continuous.

- With/Without intelligent adversaries
  - if the environment contains intelligent, adversarial agents, the agent needs to be concerned about strategic, game-theoretic aspects of the environment
  - most engineering environments don't have rational adversaries, whereas most social and economic systems get their complexity from the interactions of (more or less) rational agents.

Properties of Environments

	Accessible	Deterministic	Episodic	Static	Discrete
Image Classification					
Solitaire					
Backgammon					
Taxi driving					
Internet shopping					
Medical diagnosis					

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$\Rightarrow$ lots of real-world domains fall into the hardest case

summary

Summary

- An **agent** perceives and acts in an environment, has an architecture, and is implemented by an agent program.
- An **ideal agent** always chooses the action which maximizes its expected performance, given its percept sequence so far.
- An **autonomous agent** uses its own experience rather than built-in knowledge of the environment by the designer.
- An **agent program** maps from percept to action and updates its internal state.
  - **reflex agent** responds immediately to percepts.
  - **goal-based agent** acts in order to achieve their goal(s).
  - **utility-based agent** maximizes their own utility function.
- **Representing knowledge** is important for successful agent design.
- Most challenging environments are inaccessible, nondeterministic, nonepisodic, dynamic, and continuous, and contain intelligent adversaries.