# Intelligent Agents

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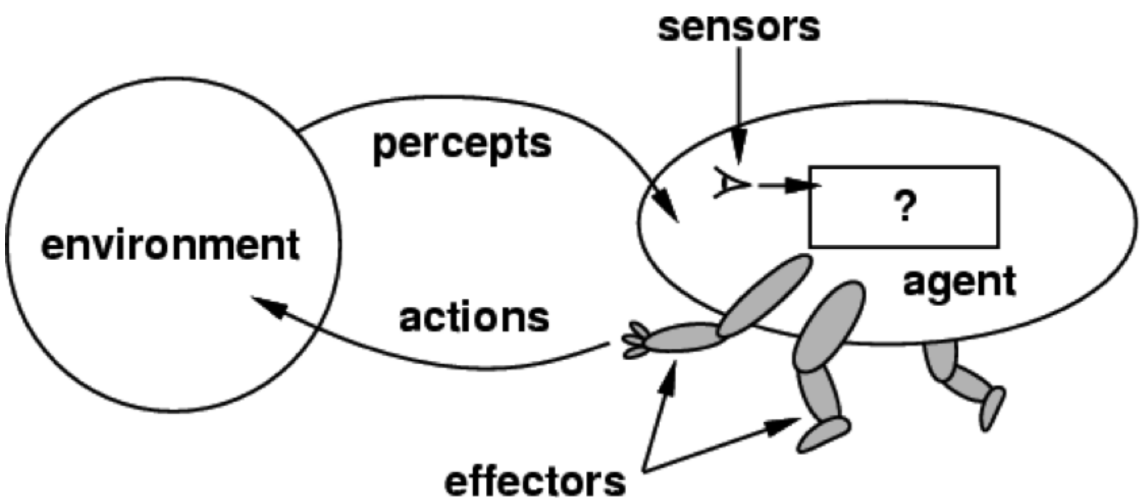
# Agents and Environments






- Agents include humans, robots, softbots, thermostats, etc.

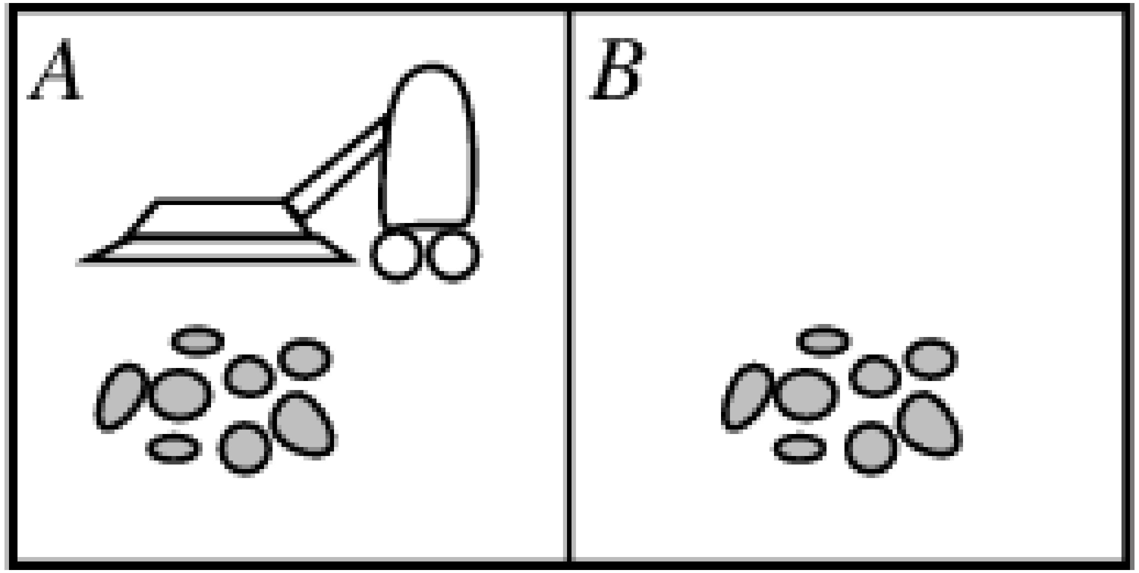
- The agent function maps from percept histories to actions:

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

- 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 |
|---|---|
| $[A, Clean]$ | $Right$ |
| $[A, Dirty]$ | $Suck$ |
| $[B, Clean]$ | $Left$ |
| $[B, Dirty]$ | $Suck$ |
| $[A, Clean], [A, Clean]$ | $Right$ |
| $[A, Clean], [A, Dirty]$ | $Suck$ |
| $\vdots$ | $\vdots$ |

**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

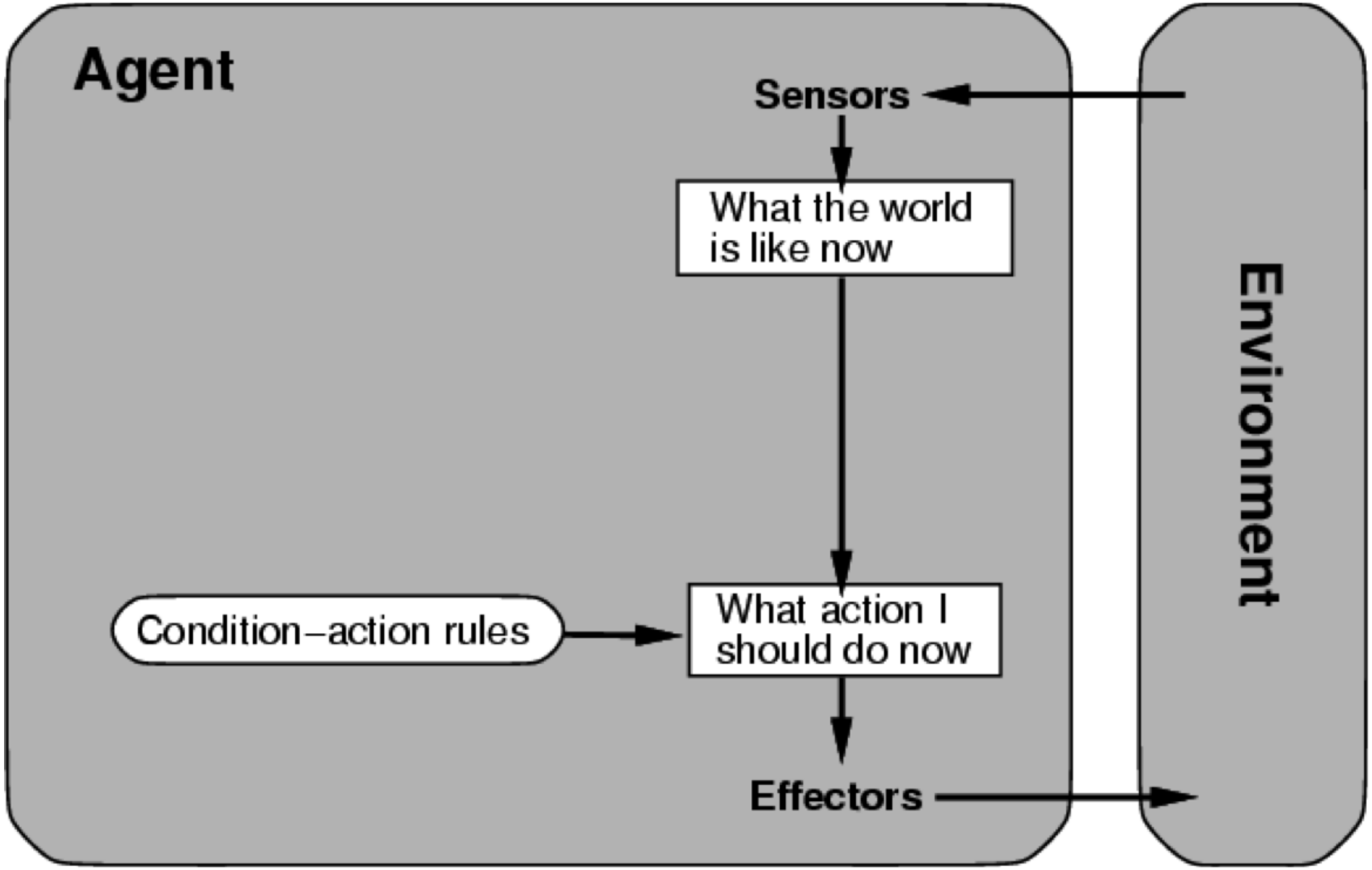
# Agent Types



- **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.

# Architecture of Table-Driven/Reflex Agent





# 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

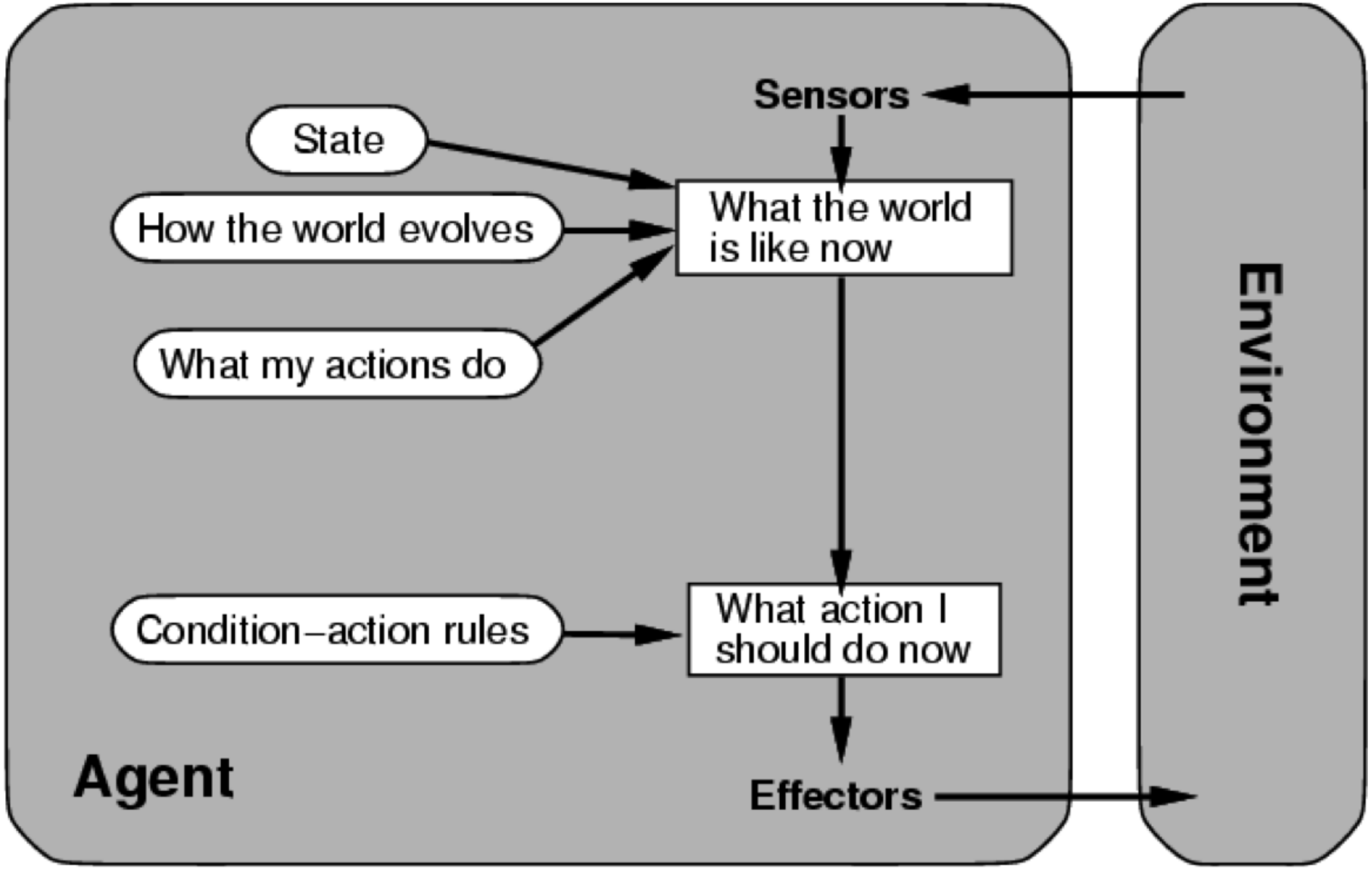
# Simple Reflex Agents

- **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 Agent with Memory





# 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

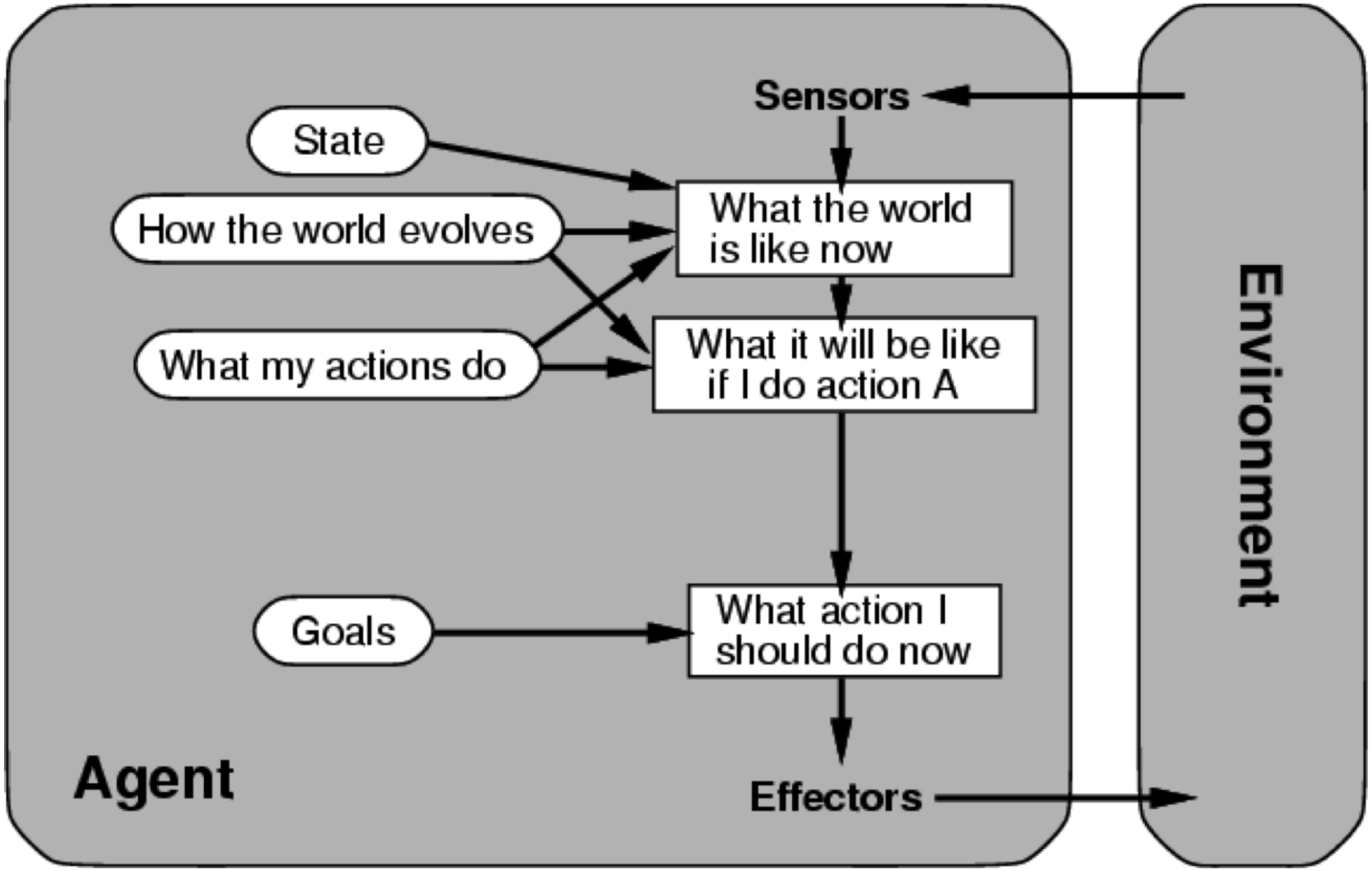
- Examples:
  - avoiding contact
  - wandering
  - exploring
  - recognizing doorways

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

- Behaviors are loosely coupled, asynchronous interactions

# Architecture of Goal-Based Agent





# Goal-Based Agent



- Choose actions so as to achieve a (given or computed) goal.

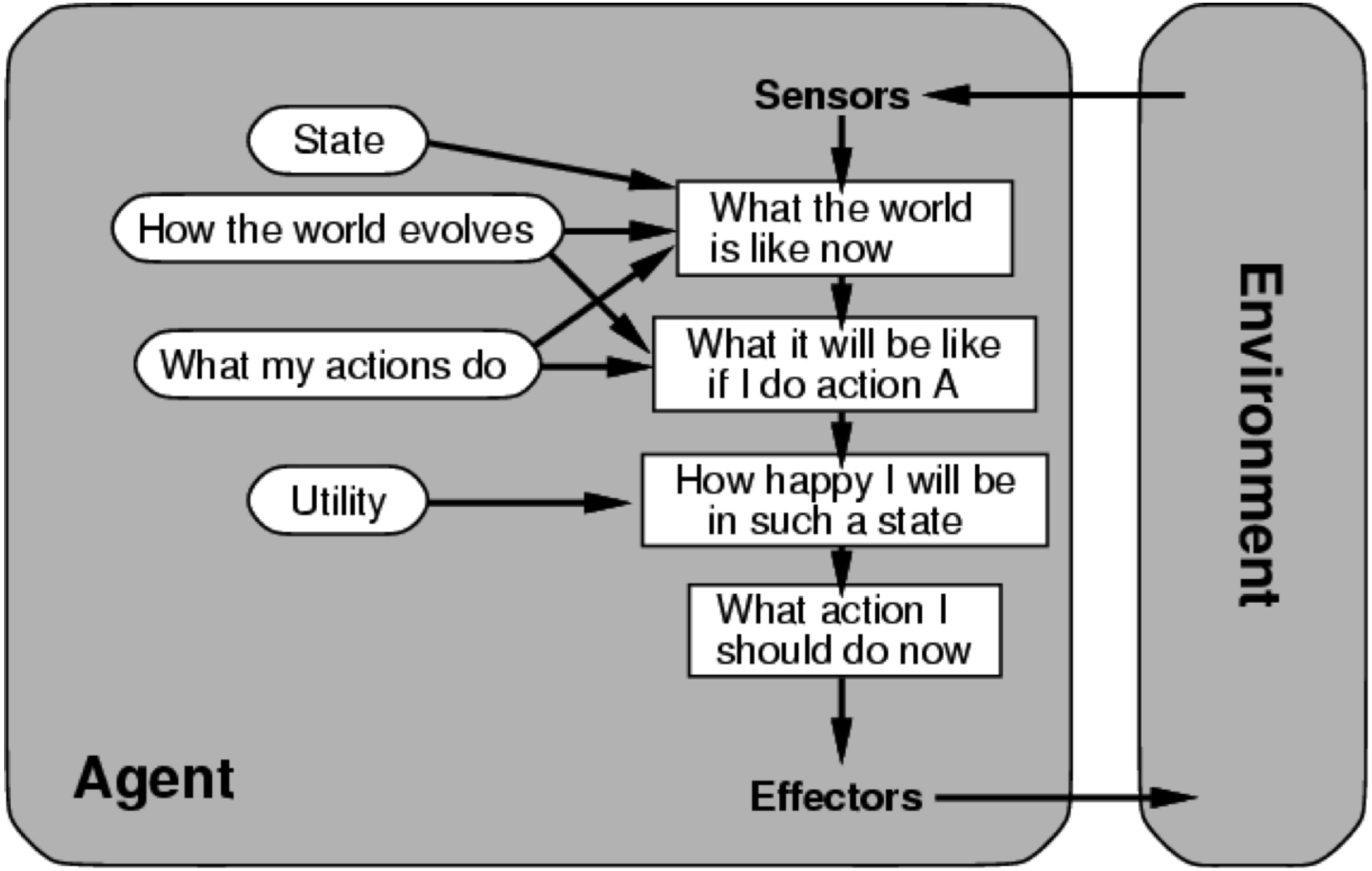
- A goal is a description of a desirable situation.

- 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 Utility-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

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

  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).

# 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.