

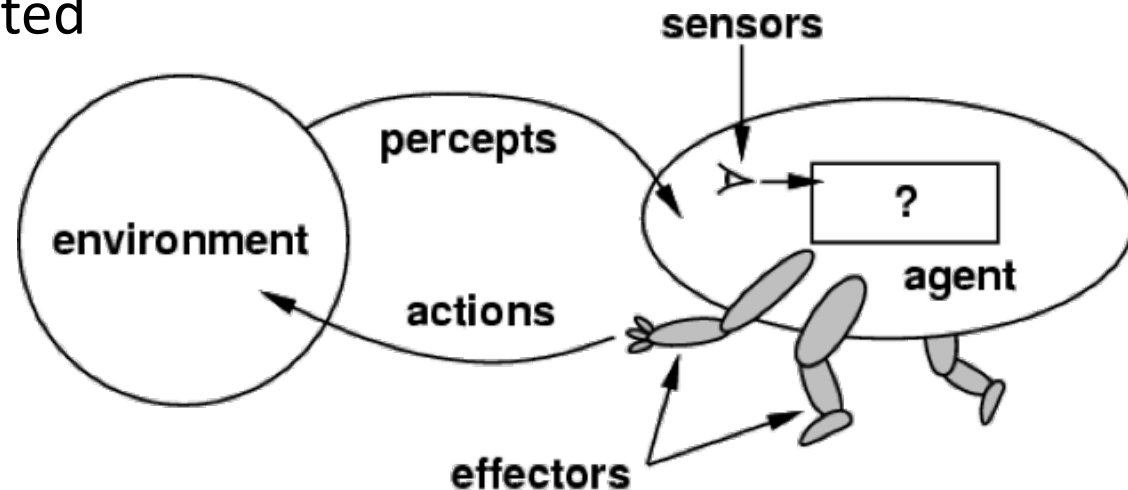


# Intelligent Agents

Chapter 2

# How do you design an intelligent agent?

- **Intelligent agents** perceive environment via **sensors** and act rationally on them with their **effectors**
- Discrete agents receive **percepts** one at a time, and map them to a sequence of discrete **actions**
- General properties
  - Reactive to the environment
  - Pro-active or goal-directed
  - Interacts with other agents through communication or via the environment
  - Autonomous



# sensors/percepts and effectors/actions ?

## Humans have

- **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, ...
- **The Point:** percepts and actions need to be carefully defined, possibly at different levels of abstraction

# Example: autonomous taxi



- **Percepts:** Video, sonar, speedometer, odometer, engine sensors, keyboard input, microphone, GPS, ...
- **Actions:** Steer, accelerate, brake, horn, speak, ...
- **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

- Ideal **rational agents** should, for each percept sequence, act to maximize expected performance measure based on
  - (1) the percept sequence, and
  - (2) its built-in and acquired knowledge
- Rationality includes information gathering -- If you don't know something, find out!
- Rationality → Need a performance measure to say how well a task has been achieved
- Types of performance measures: false alarm (false positive) and false dismissal (false negative) rates, speed, resources required, effect on environment, etc.

# Autonomy



- A system is autonomous to extent that its behavior is determined by its experience
- A system isn't autonomous if guided by its designer according to a priori decisions
- An autonomous agent can always say “no”
- To survive, agents must have:
  - Enough built-in knowledge to survive
  - The ability to learn

# Some agent types

## (0) Table-driven agents

- Use percept sequence/action table to find the next action. Implemented by a (large) **lookup table**

## (1) Simple reflex agents

- Based on **condition-action rules**, implemented with an appropriate production system; stateless devices with no memory of past world states

## (2) Agents with memory

- have **internal state** used to keep track of past states of the world

## (3) Agents with goals

- Agents with a state and **goal information** describing desirable situations. Agents of this kind take future events into consideration.

## (4) Utility-based agents

- base decisions on **classic axiomatic utility theory** in order to act rationally

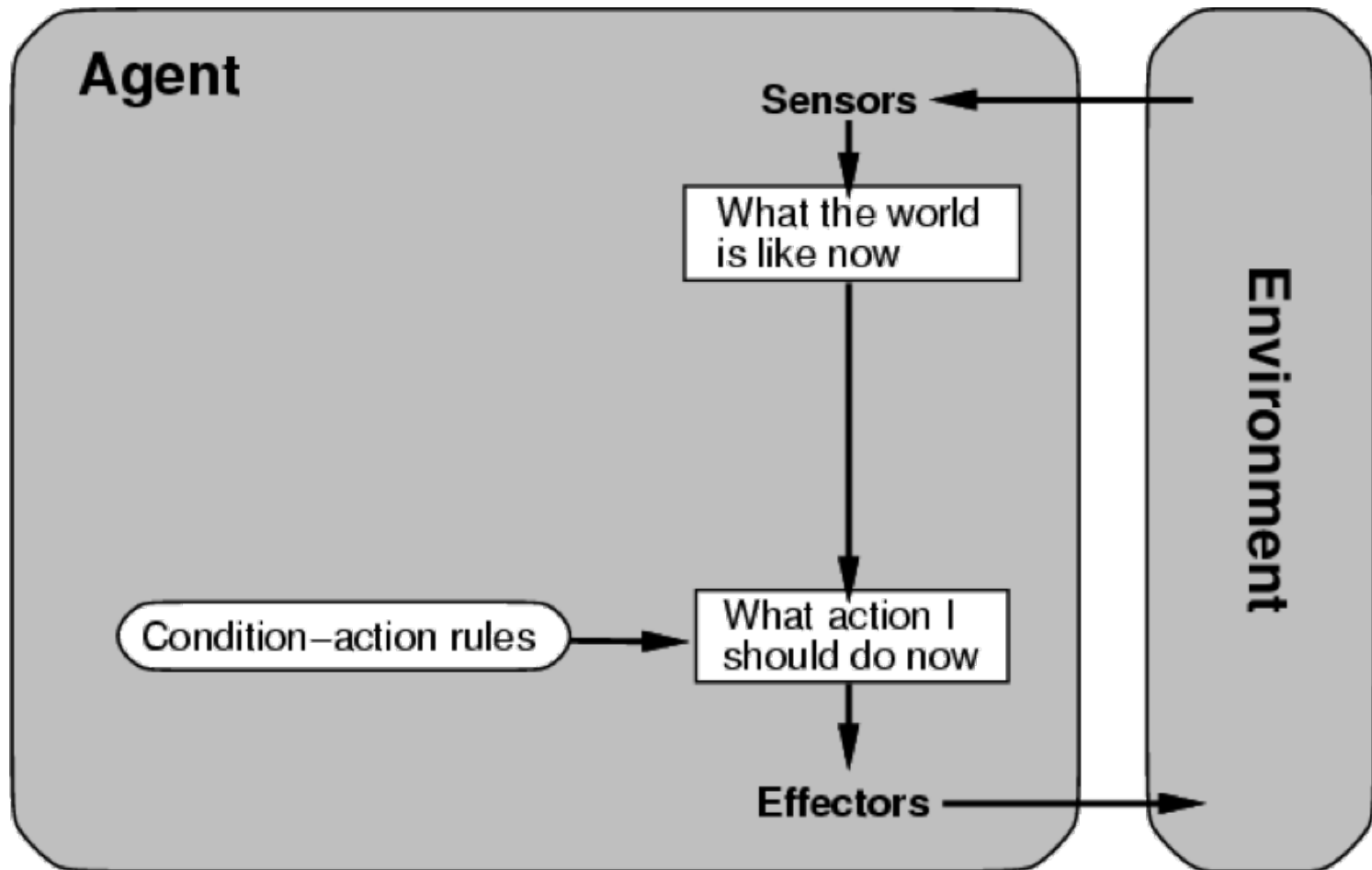
simple



complex

# (0/1) Table-driven/reflex agent architecture

Use percept sequence/action table to find the next action.  
Implemented by a (large) **lookup table**





# (0) Table-driven agents

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

## **Problems:**

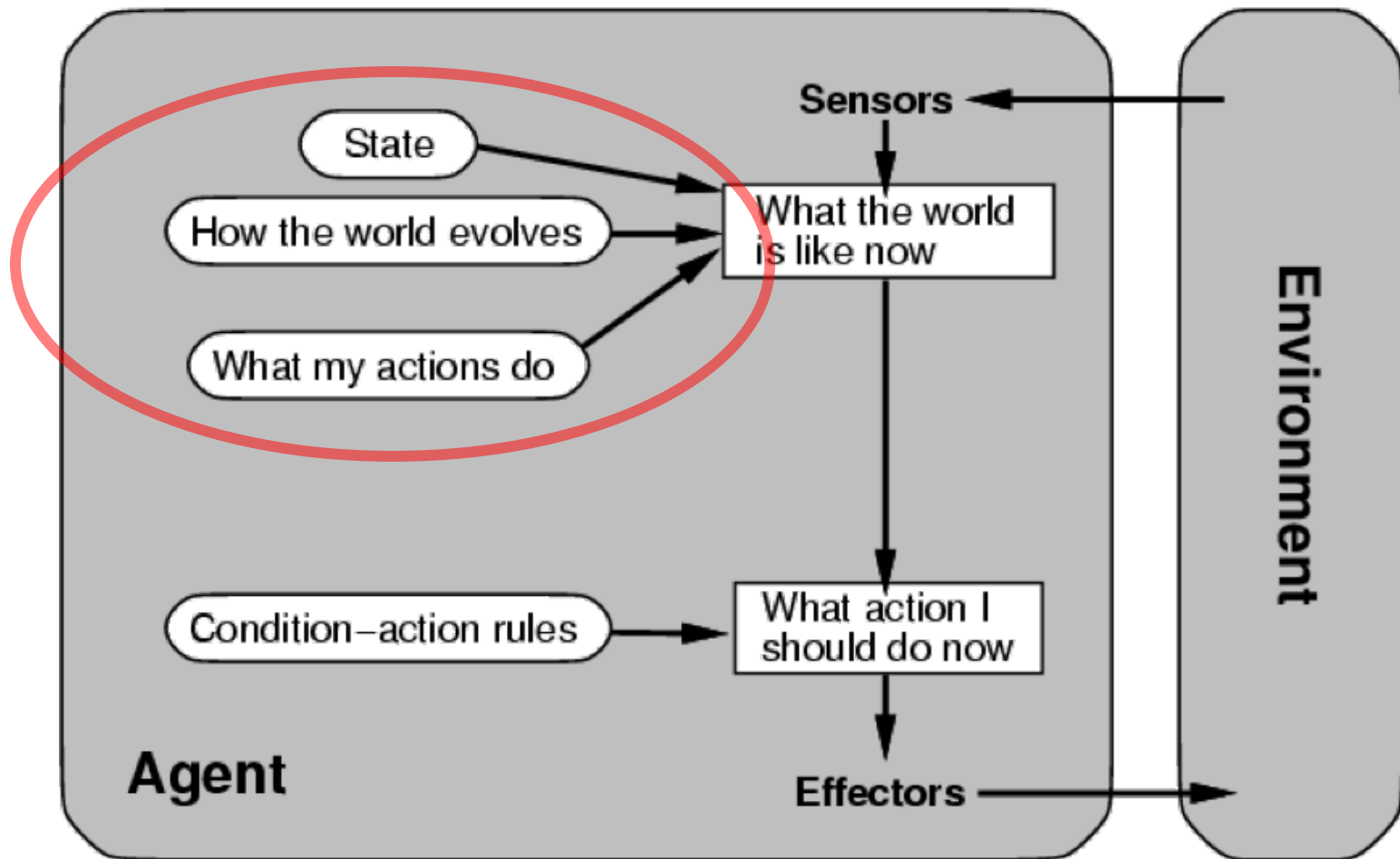
- Too big to generate and to store (Chess has about  $10^{120}$  states, for example)
- No knowledge of non-perceptual parts of the current state
- Not adaptive to changes in the environment; entire table must be updated if changes occur
- Looping: Can't make actions conditional on previous actions/states

# (1) Simple reflex agents

- **Rule-based reasoning** maps percepts to optimal action; each rule handles collection of perceived states (aka reactive agents)
- **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 environment; collection of rules must be updated if changes occur
  - Still can't condition actions on previous state
  - Difficult to engineer if the number of rules is large due to conflicts

## (2) Architecture for an agent with memory

**internal state** used to keep track of past states of the world

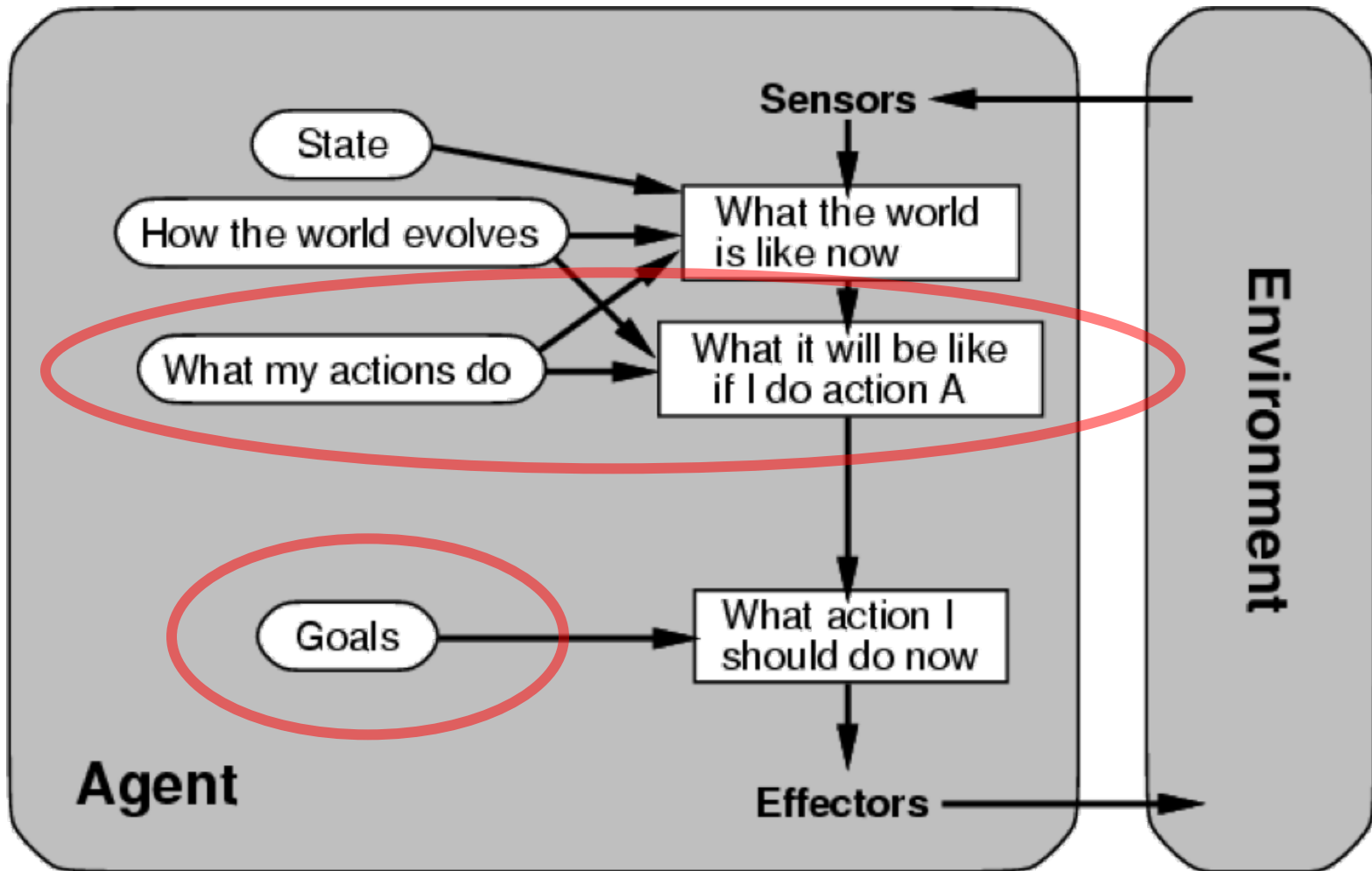


## (2) Agents with memory

- Encode *internal state* of world to remember past as contained in earlier percepts
  - Note: sensors don't usually give entire world state at each input, so environment perception is *captured over time*.
  - *State* used to encode different "world states" that generate the same immediate percept
- Requires *representing change* in the world
  - We might represent just latest state, but then can't reason about hypothetical courses of action

### (3) Architecture for goal-based agent

state and **goal information** describe desirable situations allowing agent to take future events into consideration



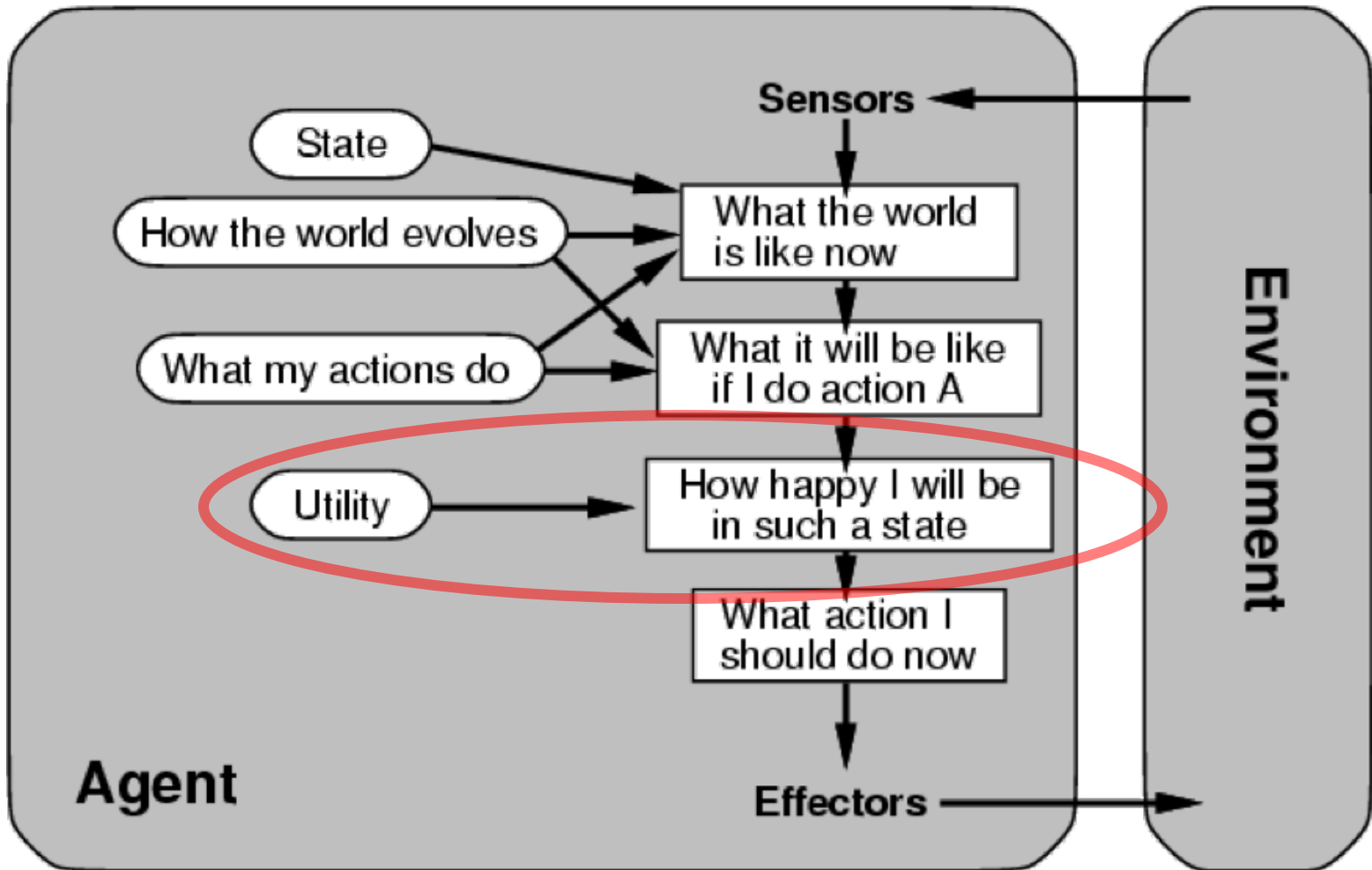
# (3) Goal-based agents



- **Deliberative** instead of **reactive**
- Choose actions to achieve a goal
- Goal is a description of a desirable situation
- Keeping track of current state often not enough: must add goals to decide which situations are good
- Achieving goal may require long action sequence
  - Model action consequences: “*what happens if I do...?*”
  - Use *planning* algorithms to produce action sequences

# (4) a complete utility-based agent

base decisions on utility theory in order to act rationally



## (4) Utility-based agents

- For multiple possible alternatives, how to decide which is best?
- Goals give a crude distinction between happy and unhappy states, but often need a performance measure for *degree*
- Utility function **U: State**→**Reals** gives measure of success/happiness for given state
- Allows decisions comparing choices between conflicting goals and likelihood of success and importance of goal (if achievement **uncertain**)



# Properties of Environments

- **Fully/Partially observable**

- If agent's sensors give complete state of environment needed to choose action, environment is **fully observable**
- Such environments are convenient, freeing agents from keeping track of the environment's changes

- **Deterministic/Stochastic**

- Environment is **deterministic** if next state is completely determined by current state and agent's action
- **Stochastic** (i.e., non-deterministic) environments have multiple, unpredictable outcomes

- In fully observable, deterministic environments agents need not deal with uncertainty

# Properties of Environments

- **Episodic/Sequential**

- In **episodic** environments subsequent episodes don't depend on actions in previous episodes
- In **sequential** environments agent engages in a series of connected episodes
- Episodic environments don't require agent to plan ahead

- **Static/Dynamic**

- **Static** environments doesn't change as agent is thinking
- The passage of time as agent deliberates is irrelevant
- The agent needn't observe world during deliberation

# Properties of Environments III

- **Discrete/Continuous**

- If number of distinct percepts and actions is limited, environment is **discrete**, otherwise it's **continuous**

- **Single agent/Multiagent**

- In environments with other agents, agent must consider strategic, [game-theoretic](#) aspects of environment (for either cooperative *or* competitive agents)

- Most engineering environments don't have multiagent properties, whereas most social and economic systems get their complexity from interactions of (more or less) rational agents

# Characteristics of environments

	Fully observable?	Deterministic?	Episodic?	Static?	Discrete?	Single agent?
Solitaire						
Backgammon						
Taxi driving						
Internet shopping						
Medical diagnosis						

A **Yes** in a cell means that aspect is simpler; a **No** more complex

# Characteristics of environments

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Solitaire	<b>No</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
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# Characteristics of environments

→ Lots of real-world domains fall into the hardest case!

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Solitaire	No	Yes	Yes	Yes	Yes	Yes
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Medical diagnosis	<b>No</b>	<b>No</b>	<b>No</b>	<b>No</b>	<b>No</b>	<b>Yes</b>

A **Yes** in a cell means that aspect is simpler; a **No** more complex

# Summary

- **Agents** perceive and act in an environment, have an architecture and are implemented by an agent program
- **Ideal agents** chooses actions to maximize their expected performance, given percept sequence so far
- **Autonomous agents** use own experience rather than built-in knowledge of environment by designer

# Summary

- **Agent programs** map percepts to actions and update their internal state
  - **Reflex** agents respond immediately to percepts
  - **Goal-based** agents act to achieve their goal(s)
  - **Utility-based** agents maximize their utility function
- **Representing knowledge** is important for good agent design
- Most challenging environments are **partially observable, stochastic, sequential, dynamic, and continuous** and contain **multiple agents**

# Summary

- Not all AI problems a good fit for or require an agent model, e.g., playing solitaire
- Nor are many AI tasks you might be asked to solve:
  - Classify movie reviews as negative, neutral or positive
  - Locate faces of people in an image
  - An efficient theorem prover
  - Learn preferred thermostat settings for each hour of each day of a week