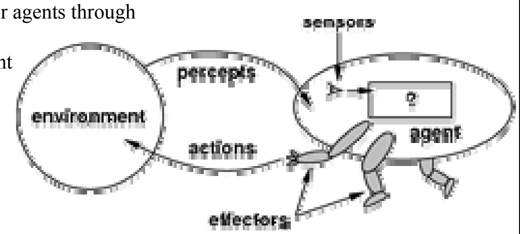
# Intelligent Agents

## Chapter 2

## How do you design an intelligent agent?

- 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
  - Reactive to the environment
  - Pro-active or goal-directed
  - Interacts with other agents through communication or via the environment
  - Autonomous




## What do you mean, sensors/percepts and effectors/actions?

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

## A more specific example: Automated taxi driving system

- **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
  - (1) the percept sequence, and
  - (2) its built-in and acquired knowledge.
- Rationality includes information gathering, not "rational ignorance." (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 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.
- 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

simple

**(0) Table-driven agents**

- use a percept sequence/action table in memory 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** that is used to keep track of past states of the world

**(3) Agents with goals**

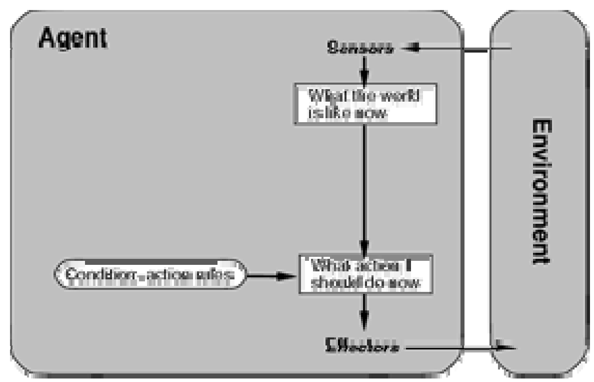
- Agents that have state and **goal information** that describes desirable situations. Agents of this kind take future events into consideration.

**(4) Utility-based agents**

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

complex

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



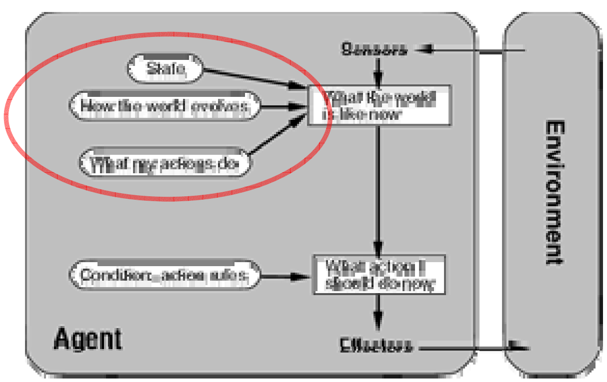
# (0) Table-driven agents

- **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

# (1) Simple reflex agents

- **Rule-based reasoning** to map from percepts to optimal action; each rule handles a collection of perceived states
- Sometimes called 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 the environment; requires collection of rules to be updated if changes occur
  - Still can’t make actions conditional on previous state
  - Can be difficult to engineer if the number of rules is large due to conflicts

# (2) Architecture for an agent with memory

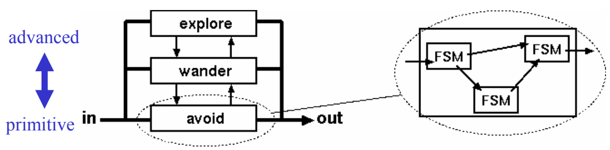



# (2) Agents with memory

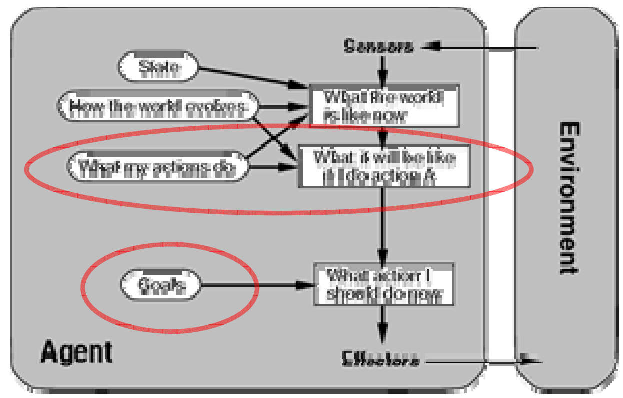
- Encode “internal state” of the world to remember the past as contained in earlier percepts.
- Note: sensors don’t usually give the entire world state at each input, so environment perception is *captured over time*. “State” is used to encode different "world states" that generate the same immediate 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.

## (2) Brooks's Subsumption Architecture

- Rod Brooks, director of MIT AI Lab
- Main idea: build complex, intelligent robots by decomposing behaviors into hierarchy of skills, each completely defining a complete percept-action cycle for one very specific task.
- Examples: avoiding contact, wandering, exploring, recognizing doorways, etc.
- Each behavior modeled by a finite-state machine with a few states (tho each may correspond to complex function/module).
- Behaviors are loosely coupled, asynchronous interactions.



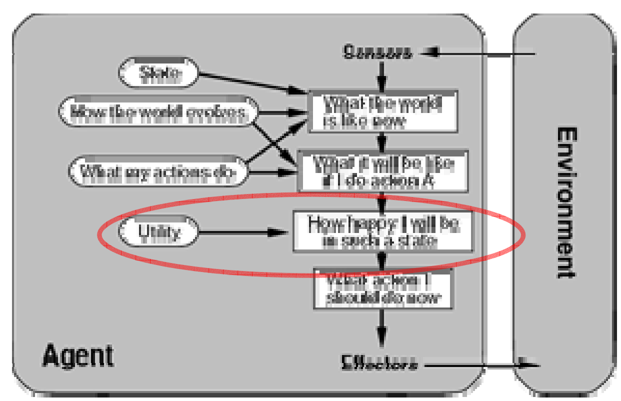

## (3) Architecture for goal-based agent




## (3) Goal-based agents

- **Deliberative** instead of **reactive**
- Choose actions so as to achieve a goal (given or computed)
- 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
- Achieving a goal may require a long action sequence
  - Must model action consequences: *"what will happen if I do...?"*
  - Planning

## (4) a complete utility-based agent



## (4) Utility-based agents

- When there are multiple possible alternatives, how to decide which one is best?
- Goals specify a crude distinction between a happy and unhappy states, but often need a performance measure that describes "degree of happiness."
- Utility function **U: State → Reals** indicating a measure of success or happiness for a given state
- Allows decisions comparing choice between conflicting goals, and choice between likelihood of success and importance of goal (if achievement is uncertain).

## Properties of Environments

- **Fully/Partially observable**
  - If an agent's sensors give it access to the complete state of the environment needed to choose an action, the environment is **fully observable**.
  - Such environments are convenient, freeing agents from keeping track of the environment's changes.
- **Deterministic/Stochastic**
  - An environment is **deterministic** if the next state of the environment is completely determined by the current state and the agent's action; in a **stochastic** environment, there are multiple, unpredictable outcomes
- In a fully observable, deterministic environment, agents need not deal with uncertainty

## Properties of Environments II

- **Episodic/Sequential**
  - An **episodic** environment means that subsequent episodes do not depend on what actions occurred in previous episodes.
  - In a **sequential** environment, the agent engages in a series of connected episodes.
  - Such environments don't require the agent to plan ahead.
- **Static/Dynamic**
  - A **static** environment doesn't change as the agent is thinking
  - The passage of time as an agent deliberates is irrelevant
  - The agent needn't observe the world during deliberation

## Properties of Environments III

- **Discrete/Continuous**
  - If the number of distinct percepts and actions is limited, the environment is **discrete**, otherwise it is **continuous**.
- **Single agent/Multiagent**
  - If the environment contains other intelligent agents, the agent must be concerned about strategic, game-theoretic aspects of the 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 the 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 | | | | | | |

# Characteristics of environments

| | Accessible | Deterministic | Episodic | Static | Discrete? | Single agent? |
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| Medical diagnosis | **No** | **No** | **No** | **No** | **No** | **Yes** |

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

## 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 agents** respond immediately to percepts
  - **Goal-based agents** act in order to achieve their goal(s)
  - **Utility-based agents** maximize their own utility function
- **Representing knowledge** is important for successful agent design
- The most challenging environments are partially observable, stochastic, sequential, dynamic, and continuous, and contain multiple intelligent agents.