Introduction to Artificial Intelligence

Lecture 1: Intelligent agents

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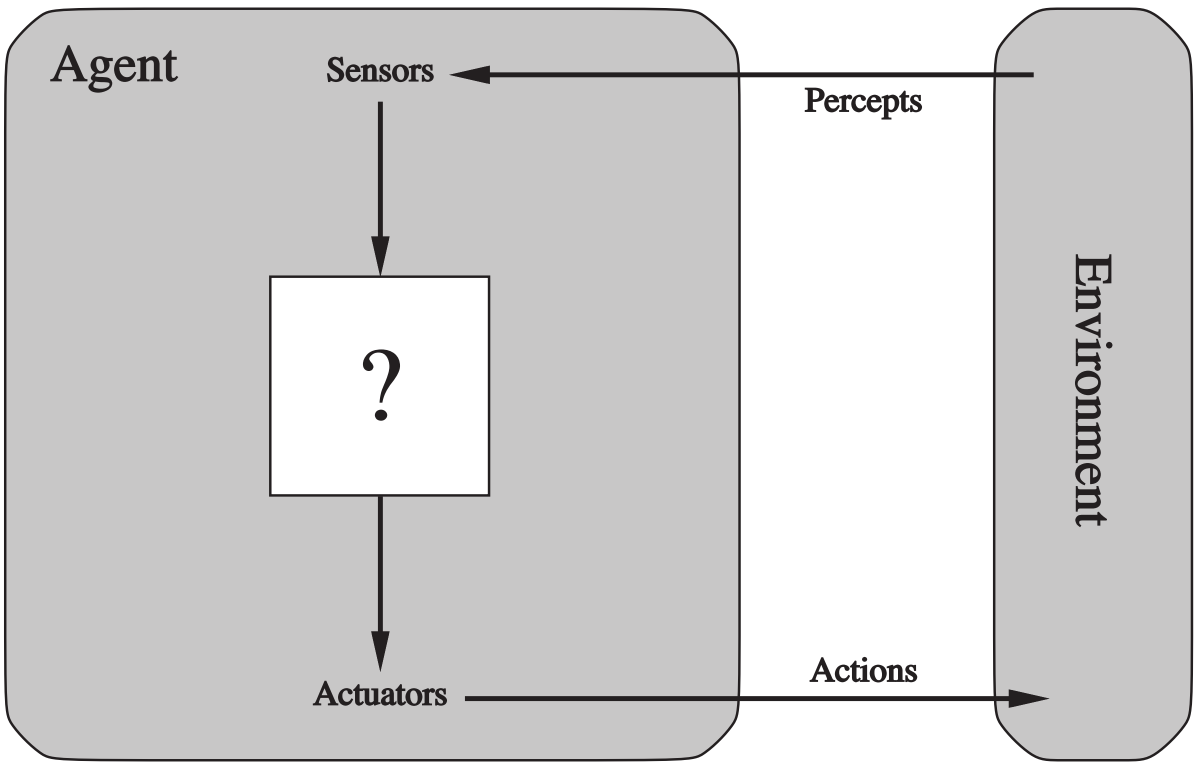
Intelligent agents

Agents and environments



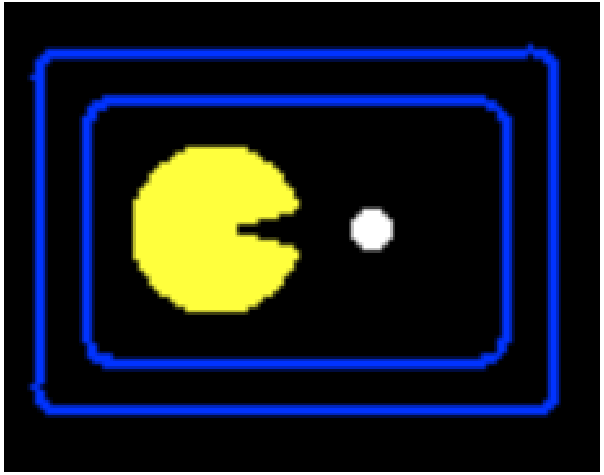
Agents

- An agent is an entity that perceives its environment through sensors and take actions through actuators.
- The agent behavior is described by the agent function, or policy, that maps percept histories to actions:

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

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

Simplified Pacman world



- Percepts: location and content, e.g. $(\text{left cell}, \text{no food})$
- Actions: go left, go right, eat, do nothing

Pacman agent

Partial tabulation of a simple Pacman agent function:

Percept sequence	Action
(left cell,no food)	go right
(left cell,food)	eat
(right cell,no food)	go left
(left cell,food)	eat
(left cell,no food),(left cell,no food)	go right
(left cell,no food),(left cell,food)	eat
(...)	(...)

The optimal Pacman?

What is the right agent function? How to formulate the goal of Pacman?

- 1 point per food collected up to time t?
- 1 point per food collected up to time t, minus one per move?
- penalize when too many foods are left not collected?

Can it be implemented in a small agent program?

Rational agents

- Informally, a rational agent is an agent that does the "right thing".
- A performance measure evaluates a sequence of environment states caused by the agent's behavior.
- A rational agent is an agent that chooses whichever action that maximizes the expected value of the performance measure, given the percept sequence to date.

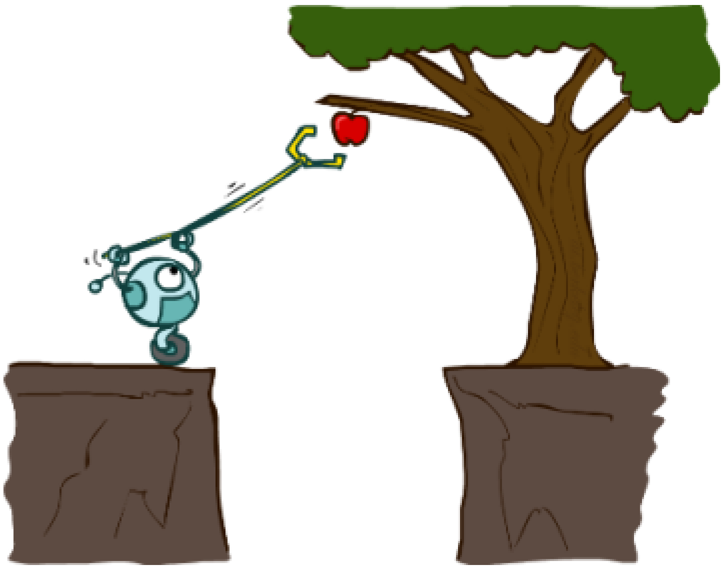


Image credits: CS188, UC Berkeley.

- Rationality $\neq$ omniscience
    - percepts may not supply all relevant information.
- Rationality $\neq$ clairvoyance
    - action outcomes may not be as expected.
- Hence, rational $\neq$ successful.
- However, rationality leads to exploration, learning and autonomy.

Performance, environment, actuators, sensors

The characteristics of the performance measure, environment, action space and percepts dictate techniques for selecting rational actions.

These characteristics are summarized as the task environment.

Example 1: an autonomous car

- performance measure: safety, destination, legality, comfort, ...
- environment: streets, highways, traffic, pedestrians, weather, ...
- actuators: steering, accelerator, brake, horn, speaker, display, ...
- sensors: video, accelerometers, gauges, engine sensors, GPS, ...

Example 2: an Internet shopping agent

- performance measure: price, quality, appropriateness, efficiency
- environment: current and future WWW sites, vendors, shippers
- actuators: display to user, follow URL, fill in form, ...
- sensors: web pages (text, graphics, scripts)

Environment types

- Fully observable vs. partially observable
    - Whether the agent sensors give access to the complete state of the environment, at each point in time.
- Deterministic vs. stochastic
    - Whether the next state of the environment is completely determined by the current state and the action executed by the agent.
- Episodic vs. sequential
    - Whether the agent's experience is divided into atomic independent episodes.
- Static vs. dynamic
    - Whether the environment can change, or the performance measure can change with time.
- Discrete vs. continuous
    - Whether the state of the environment, the time, the percepts or the actions are continuous.
- Single agent vs. multi-agent
    - Whether the environment include several agents that may interact which each other.
- Known vs unknown
    - Reflects the agent's state of knowledge of the "law of physics" of the environment.

Are the following task environments fully observable? deterministic? episodic? static? discrete? single agents? Known?

- Crossword puzzle
- Chess, with a clock
- Poker
- Backgammon
- Taxi driving
- Medical diagnosis
- Image analysis
- Part-picking robot
- Refinery controller
- The real world

Agent programs

The job of AI is to design an agent program that implements the agent function. This program will run on an architecture, that is a computing device with physical sensors and actuators.

$$\text{agent} = \text{program} + \text{architecture}$$

Implementation

Agent programs can be designed and implemented in many ways:

- with tables
- with rules
- with search algorithms
- with learning algorithms

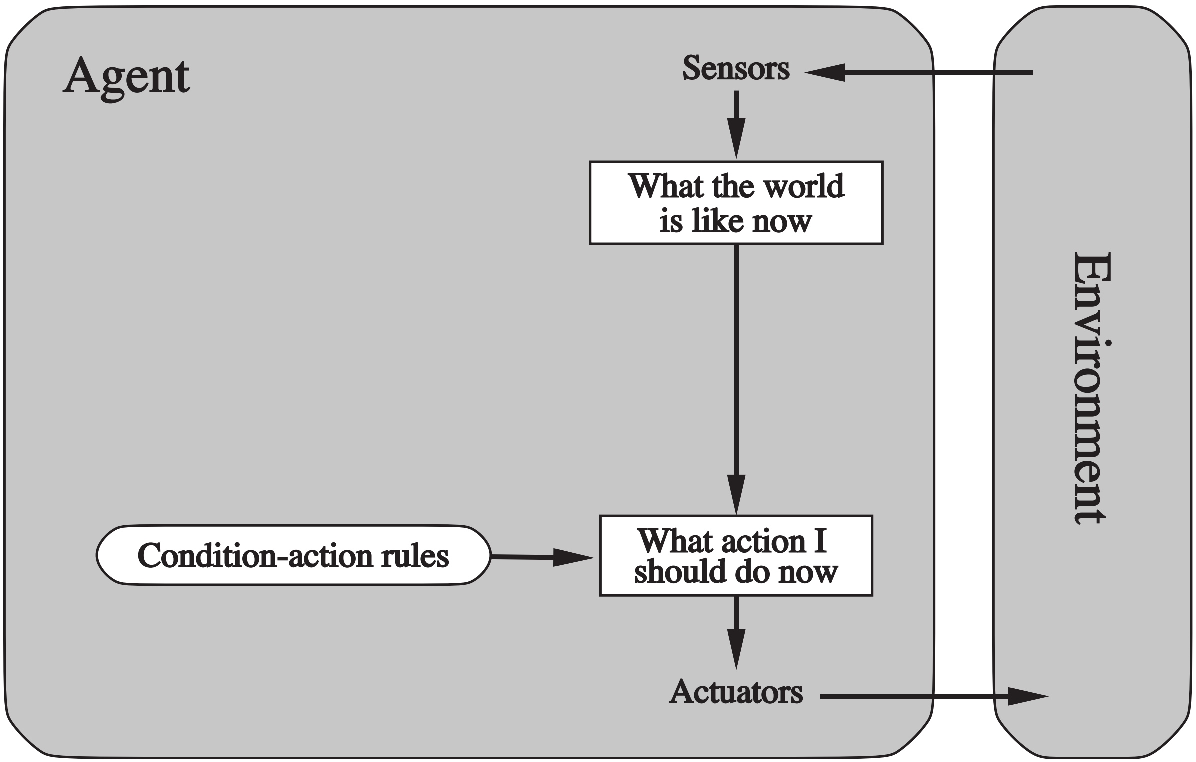
Table-driven agents

A table-driven agent determines its next action with a lookup table that contains the appropriate action for every possible percept sequence.

Issues

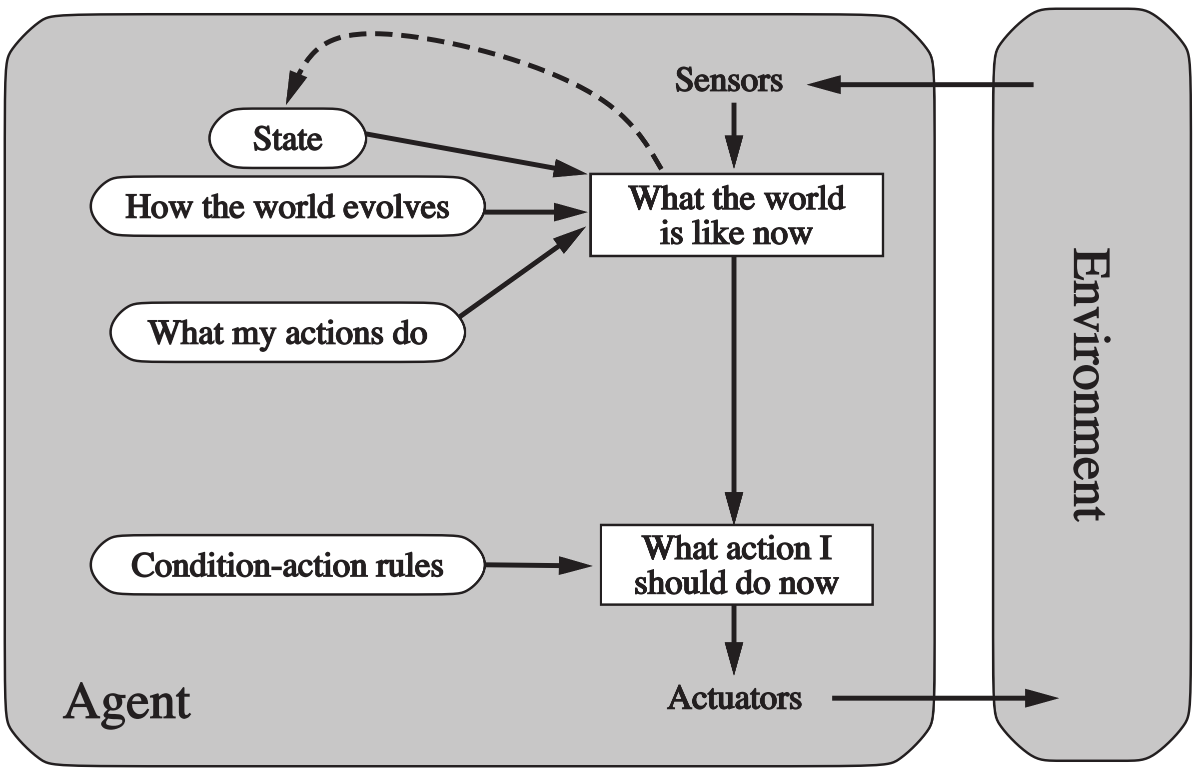
- Design issue: one needs to anticipate all sequence of percepts and how the agent should respond.
- Technical issue: the lookup table will contain $\sum_{t=1}^{T} |\mathcal{P}|^t$ entries.
- Example (autonomous car): using a 30fps 640x480 RBG camera as sensor, this results in a table with over $10^{250000000000}$ entries for an hour of driving.

Simple reflex agents



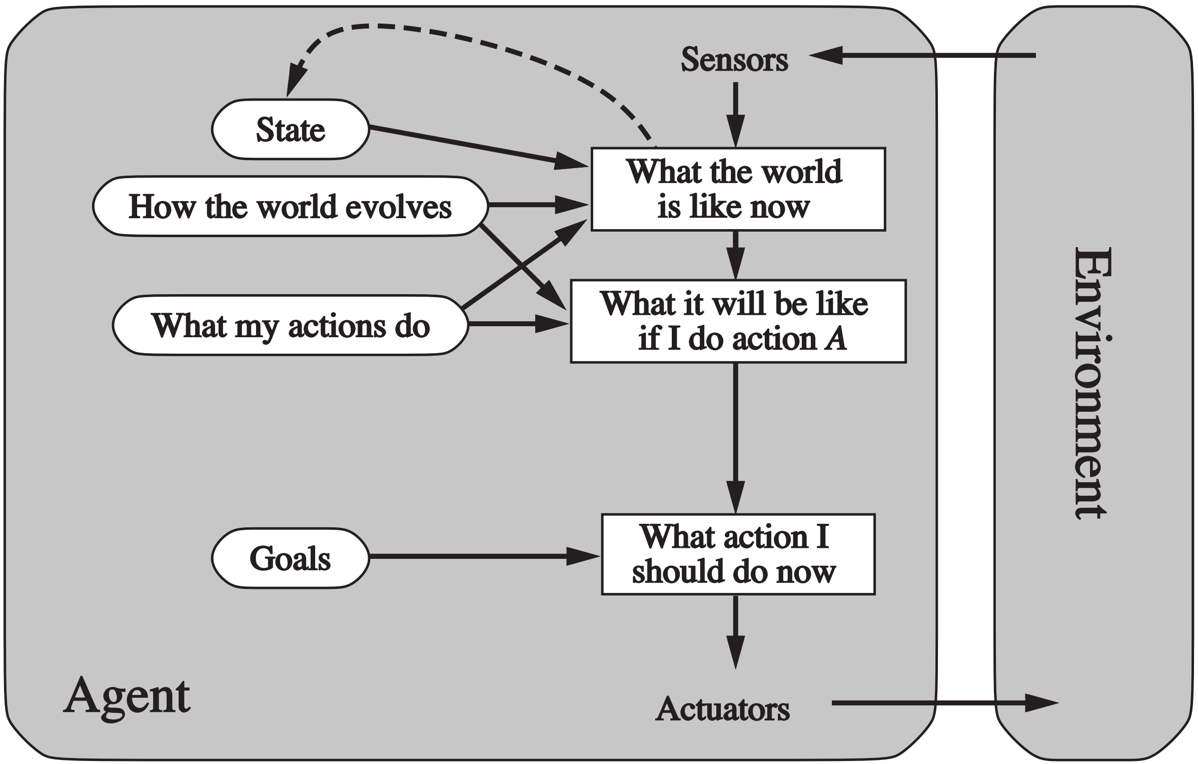
- Simple reflex agents select actions on the basis of the current percept, ignoring the rest of the percept history.
- They implement condition-action rules that match the current percept to an action.
- Rules provide a way to compress the function table.
  - Example (autonomous car): If a car in front of you slow down, you should break. The color and model of the car, the music on the radio or the weather are all irrelevant.
- Simple reflex agents are simple but they turn out to have limited intelligence.
- They can only work in a Markovian environment, that is if the correct decision can be made on the basis of only the current percept. In other words, if the environment is fully observable.

Model-based reflex agents



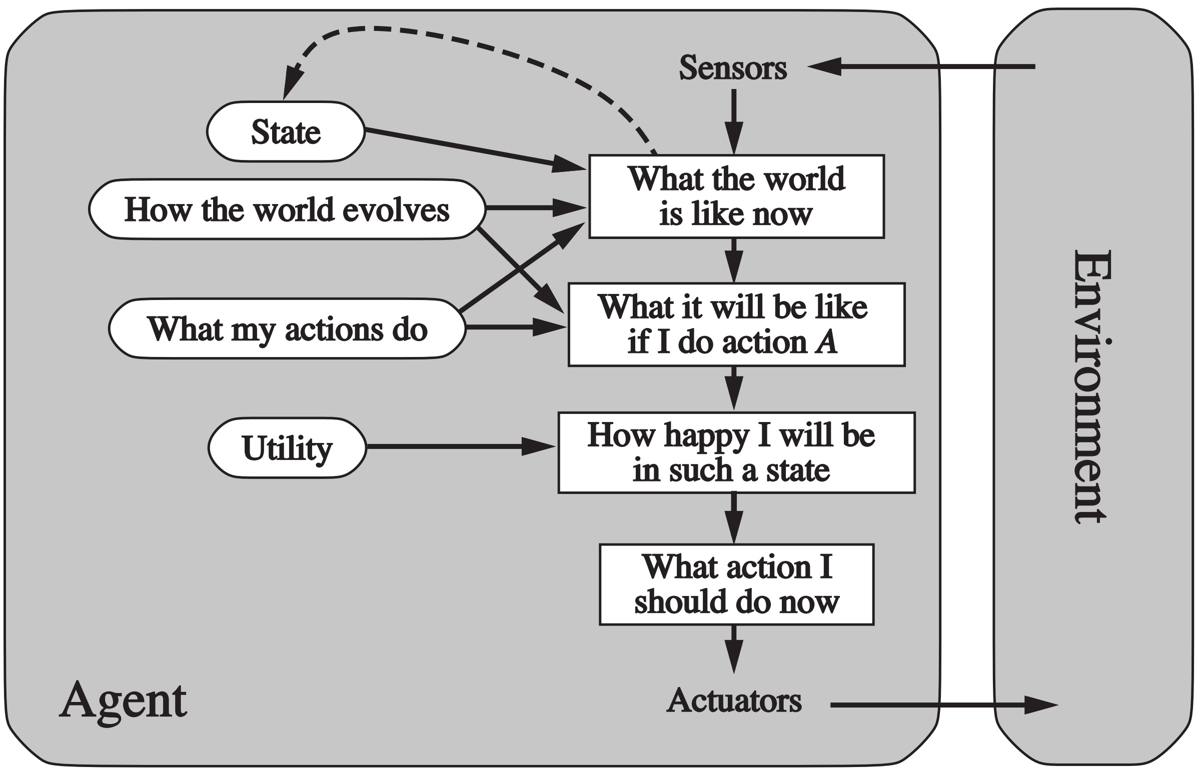
- Model-based agents handle partial observability of the environment by keeping track of the part of the world they cannot see now.
- The internal state of model-based agents is updated on the basis of a model which determines:
    - how the environment evolves independently of the agent;
    - how the agent actions affect the world.

Goal-based agents



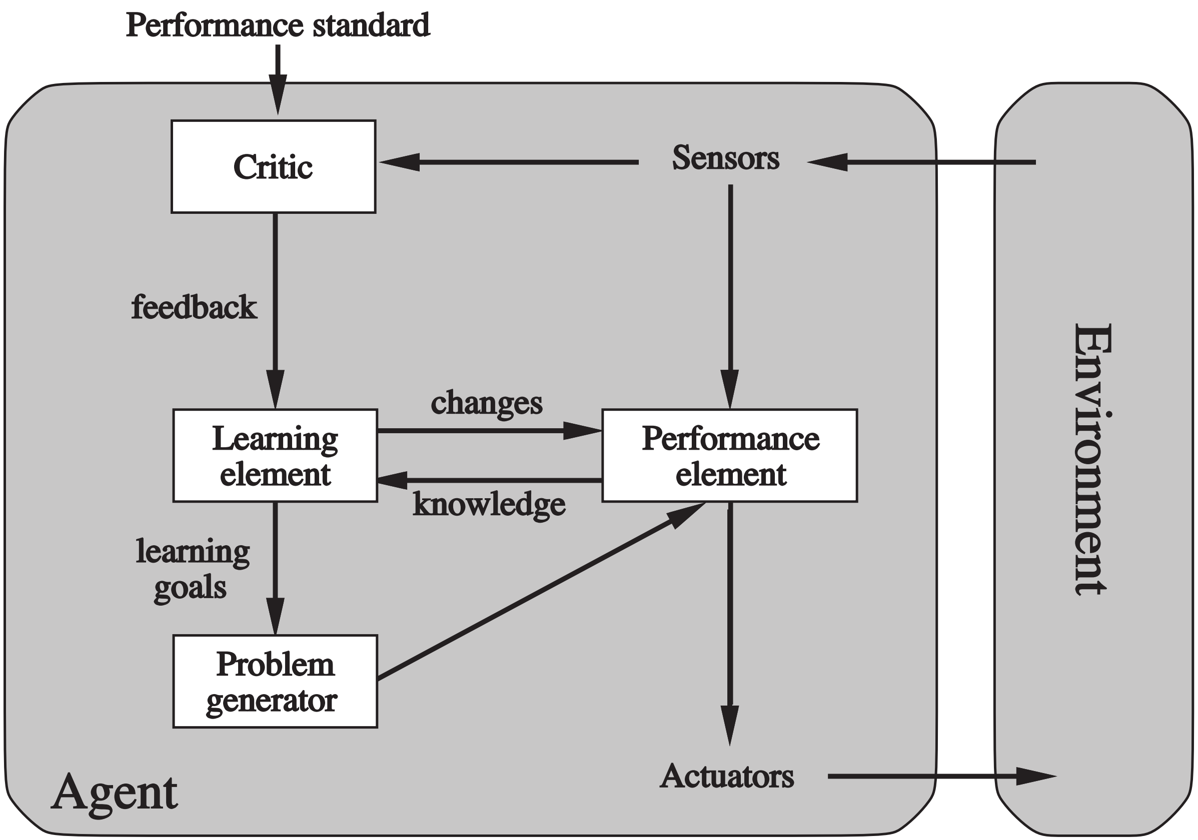
- Principle:
    1. generate possible sequences of actions
    2. predict the resulting states
    3. assess goals in each.
- A goal-based agent chooses an action that will achieve the goal.
    - More general than rules. Goals are rarely explicit in condition-action rules.
    - Finding action sequences that achieve goals is difficult. Search and planning are two strategies.
- Example (autonomous car): Has the car arrived to destination?

Utility-based agents



- Goals are often not enough to generate high-quality behavior.
  - Example (autonomous car): There are many ways to arrive to destination, but some are quicker or more reliable.
  - Goals only provide binary assessment of performance.
- A utility function scores any given sequence of environment states.
  - The utility function is an internalization of the performance measure.
- A rational utility-based agent chooses an action that maximizes the expected utility of its outcomes.

Learning agents



- Learning agents are capable of self-improvement. They can become more competent than their initial knowledge alone might allow.
- They can make changes to any of the knowledge components by:
  - learning how the world evolves;
  - learning what are the consequences of actions;
  - learning the utility of actions through rewards.

A learning autonomous car

- Performance element:
  - The current system for selecting actions and driving.
- The critic observes the world and passes information to the learning element.
  - E.g., the car makes a quick left turn across three lanes of traffic. The critic observes shocking language from the other drivers and informs bad action.
  - The learning element tries to modifies the performance element to avoid reproducing this situation in the future.
- The problem generator identifies certain areas of behavior in need of improvement and suggest experiments.
  - E.g., trying out the brakes on different surfaces in different weather conditions.

Summary

- An agent is an entity that perceives and acts in an environment.
- The performance measure evaluates the agent's behavior. Rational agents act so as to maximize the expected value of the performance measure.
- Task environments includes performance measure, environment, actuators and sensors. They can vary along several significant dimensions.
- The agent program effectively implements the agent function. Their designs are dictated by the task environment.
- Simple reflex agents respond directly to percepts, whereas model-based reflex agents maintain internal state to track the world. Goal-based agents act to achieve goals while utility-based agents try to maximize their expected performance.
- All agents can improve their performance through learning.

The end.