Chapter 02
Intelligent Agents

Instructor: LE Thanh Sach, Ph.D.

Instructor's Information

LE Thanh Sach, Ph.D.

Office:

Department of Computer Science,
Faculty of Computer Science and Engineering,
HoChiMinh City University of Technology.

Office Address:

268 LyThuongKiet Str., Dist. 10, HoChiMinh City,
Vietnam.

E-mail: LTSACH@cse.hcmut.edu.vn

E-home: http://cse.hcmut.edu.vn/~ltsach/

Tel: (+84) 83-864-7256 (Ext: 5839)

Acknowledgment

The slides in this PPT file are composed using the materials supplied by

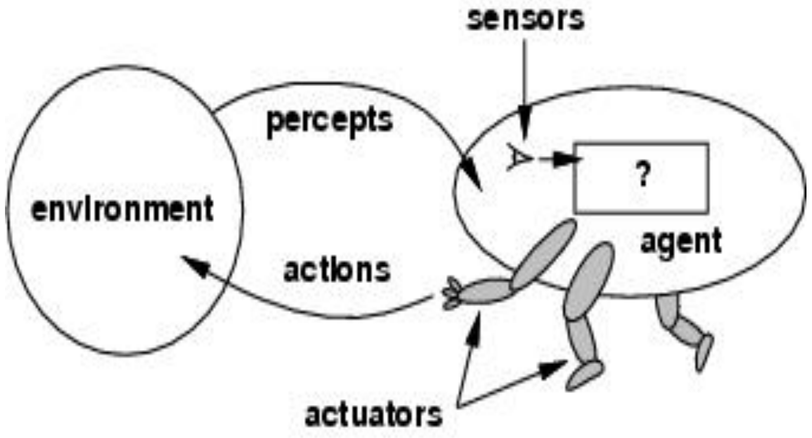
- ✍ **Prof. Stuart Russell and Peter Norvig**: They are currently from University of California, Berkeley. They are also the author of the book "Artificial Intelligence: A Modern Approach", which is used as the textbook for the course

- ✍ **Prof. Tom Lenaerts**, from Université Libre de Bruxelles

Outline

- Agents and environments.
  - The vacuum-cleaner world
- The concept of rational behavior.
- Environments.
- Agent structure.

Agents and environments

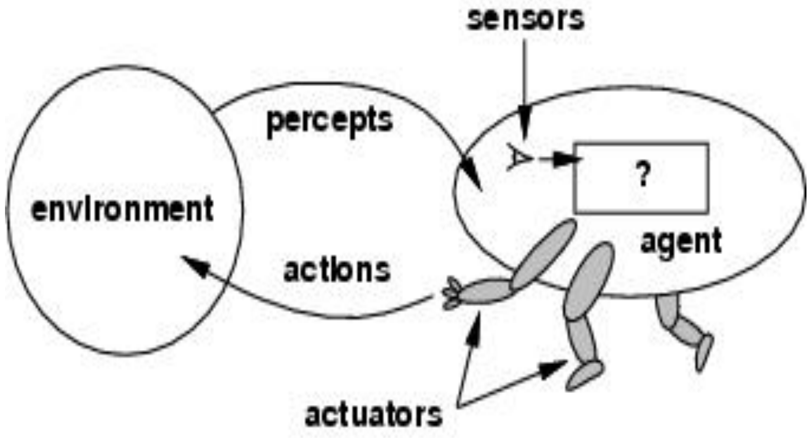


- Agents include human, robots, softbots, thermostats, etc.
- The *agent function* maps percept sequence to actions

$$f : P^* \rightarrow A$$

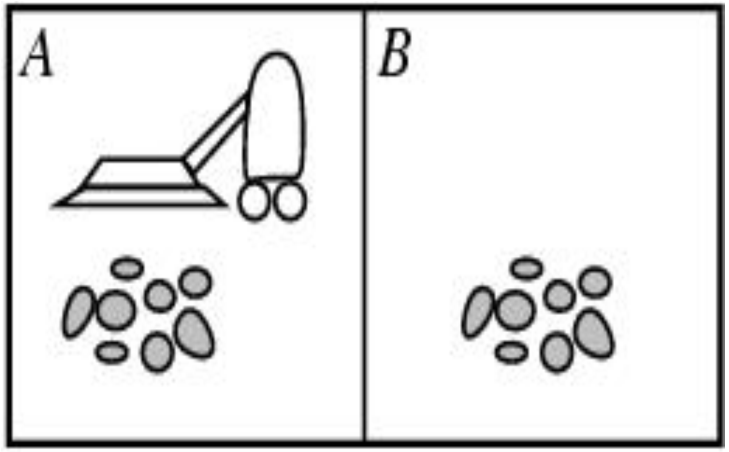
- An agent can perceive its own actions, but not always its effects.

Agents and environments



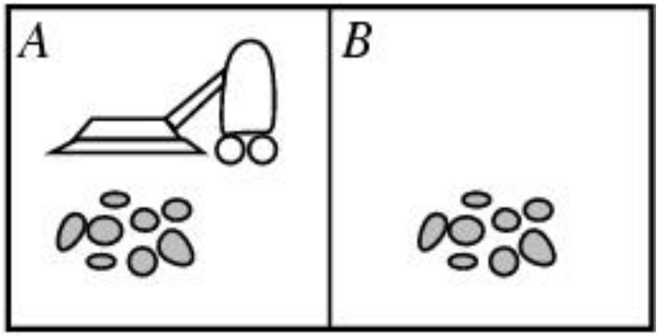
- The *agent function* will internally be represented by the *agent program*.
- The agent program runs on the physical *architecture* to produce *f*.

The vacuum-cleaner world



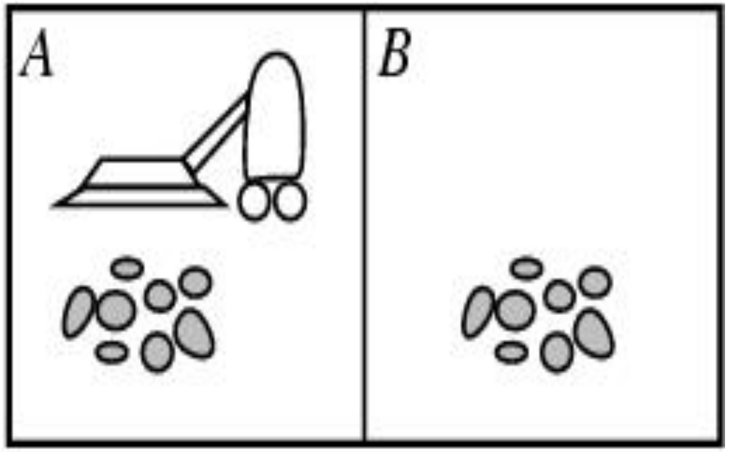
- Environment: square A and B
- Percepts: [location and content] e.g. *[A, Dirty]*
- Actions: left, right, suck, and no-op

The vacuum-cleaner world



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
…	…

The vacuum-cleaner world



```
function REFLEX-VACUUM-AGENT ([location, status]) return an action
    if status == Dirty then return Suck
    else if location == A then return Right
    else if location == B then return Left
```

What is the right function? Can it be implemented in a small agent program?

The concept of rationality

- A **rational agent** is one that does the right thing.
  - Every entry in the table is filled out correctly.
- What is the right thing?
  - Approximation: the most *successful* agent.
  - *Measure of success?*
- Performance measure should be objective
  - E.g. the amount of dirt cleaned within a certain time.
  - E.g. how clean the floor is.
  - …
- *Performance measure according to what is wanted in the environment instead of how the agents should behave.*

Rationality

- What is rational at a given time depends on four things:
  - Performance measure,
  - Prior environment knowledge,
  - Actions,
  - Percept sequence to date (sensors).
- DEF: *A rational agent chooses whichever action maximizes the expected value of the performance measure given the percept sequence to date and prior environment knowledge.*

Rationality

- Rationality ≠ omniscience
  - ✍ An omniscient agent knows the actual outcome of its actions.
- Rationality ≠ perfection
  - ✍ Rationality maximizes *expected* performance, while perfection maximizes *actual* performance.

Rationality

- The proposed definition requires:
  - Information gathering/exploration
    - ✓ To maximize future rewards
  - Learn from percepts
    - ✓ Extending prior knowledge
  - Agent autonomy
    - ✓ Compensate for incorrect prior knowledge

Environments

- To design a rational agent we must specify its task environment.
- PEAS description of the environment:
  - Performance
  - Environment
  - Actuators
  - Sensors

Environments

- ❖E.g. Fully automated taxi:
  - ✓PEAS description of the environment:
    - – Performance
      - » Safety, destination, profits, legality, comfort
    - – Environment
      - » Streets/freeways, other traffic, pedestrians, weather,, …
    - – Actuators
      - » Steering, accelerating, brake, horn, speaker/display,…
    - – Sensors
      - » Video, sonar, speedometer, engine sensors, keyboard, GPS, …

Environment types

	Solitaire	Backgammom	Internet shopping	Taxi
Observable??				
Deterministic??				
Episodic??				
Static??				
Discrete??				
Single-agent??				

Environment types

Fully vs. partially observable: an environment is full observable when the sensors can detect all aspects that are *relevant* to the choice of action.

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Episodic??				
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Single-agent??				

Environment types

Deterministic vs. stochastic: if the next environment state is completely determined by the current state the executed action then the environment is deterministic.

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Static??				
Discrete??				
Single-agent??				

Environment types

Episodic vs. sequential: In an episodic environment the agent's experience can be divided into atomic steps where the agents perceives and then performs A single action. The choice of action depends only on the episode itself

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Static??				
Discrete??				
Single-agent??				

Environment types

Static vs. dynamic: If the environment can change while the agent is choosing an action, the environment is dynamic. Semi-dynamic if the agent's performance changes even when the environment remains the same.

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Discrete??				
Single-agent??				

Environment types

Discrete vs. continuous: This distinction can be applied to the state of the environment, the way time is handled and to the percepts/actions of the agent.

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Single-agent??				

Environment types

Single vs. multi-agent: Does the environment contain other agents who are also maximizing some performance measure that depends on the current agent's actions?

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Deterministic??	YES	NO	YES	NO
Episodic??	NO	NO	NO	NO
Static??	YES	YES	SEMI	NO
Discrete??	YES	YES	YES	NO
Single-agent??				

Environment types

Single vs. multi-agent: Does the environment contain other agents who are also maximizing some performance measure that depends on the current agent's actions?

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Deterministic??	YES	NO	YES	NO
Episodic??	NO	NO	NO	NO
Static??	YES	YES	SEMI	NO
Discrete??	YES	YES	YES	NO
Single-agent??	YES	NO	NO	NO

Environment types

- The simplest environment is
  - Fully observable, deterministic, episodic, static, discrete and single-agent.
- Most real situations are:
  - Partially observable, stochastic, sequential, dynamic, continuous and multi-agent.

Agent types

- How does the inside of the agent work?
  - Agent = architecture + program

- All agents have the same skeleton:
  - Input = current percepts
  - Output = action
  - Program= manipulates input to produce output

- Note difference with agent function.

Agent types

```
Function TABLE-DRIVEN_AGENT(percept) returns an action

    static: percepts, a sequence initially empty
            table, a table of actions, indexed by percept sequence

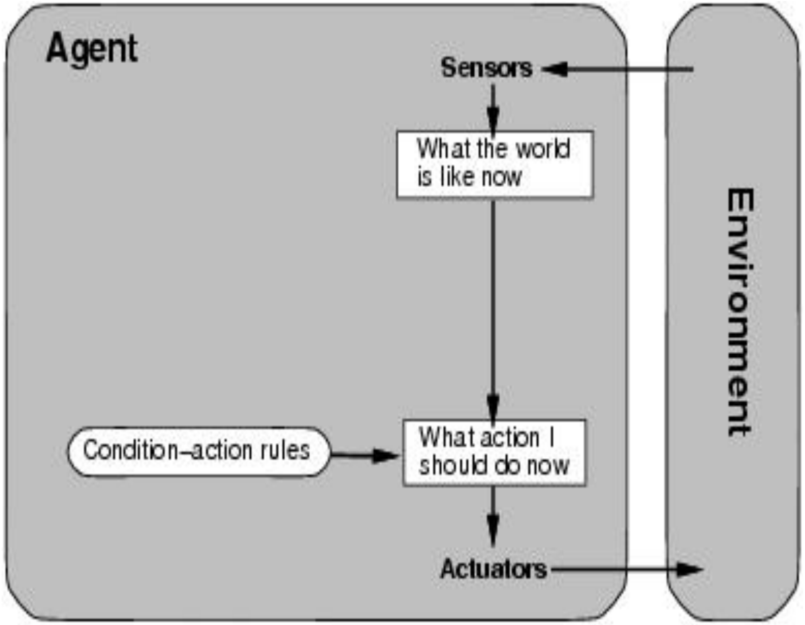
    append percept to the end of percepts
    action ← LOOKUP(percepts, table)
    return action
```

This approach is doomed to failure

Agent types

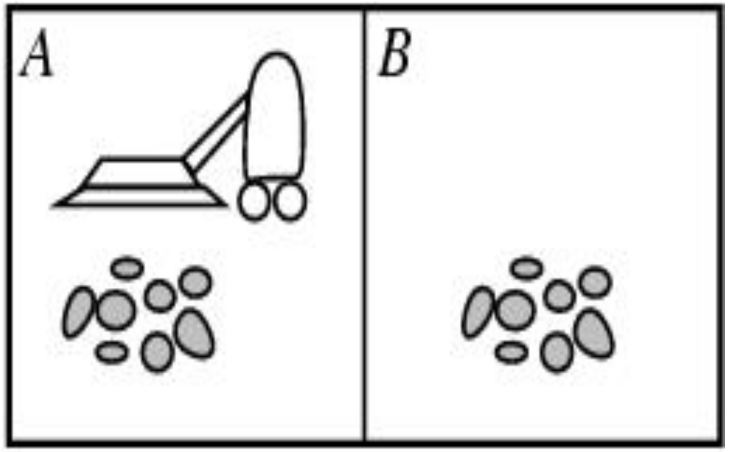
- Four basic kind of agent programs will be discussed:
  - Simple reflex agents
  - Model-based reflex agents
  - Goal-based agents
  - Utility-based agents
- All these can be turned into learning agents.

Agent types; simple reflex



- ❖ Select action on the basis of *only the current* percept.
  - ✍ E.g. the vacuum-agent
- ❖ Large reduction in possible percept/action situations (next page).
- ❖ Implemented through *condition-action rules*
  - ✍ If dirty then suck

The vacuum-cleaner world



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```

Reduction from 4^T to 4 entries

Agent types; simple reflex

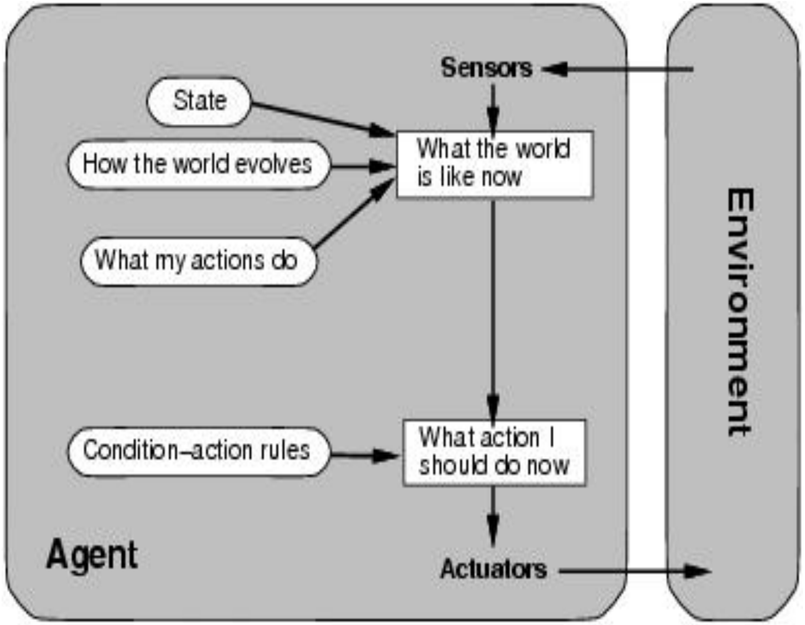
```
function SIMPLE-REFLEX-AGENT(percept) returns an action

    static: rules, a set of condition-action rules

    state ← INTERPRET-INPUT(percept)
    rule ← RULE-MATCH(state, rule)
    action ← RULE-ACTION[rule]
    return action
```

Will only work if the environment is *fully observable* otherwise infinite loops may occur.

Agent types; reflex and state



- To tackle *partially observable* environments.
  - Maintain internal state
- Over time update state using world knowledge
  - How does the world change.
  - How do actions affect world.
  - ⇒ *Model of World*

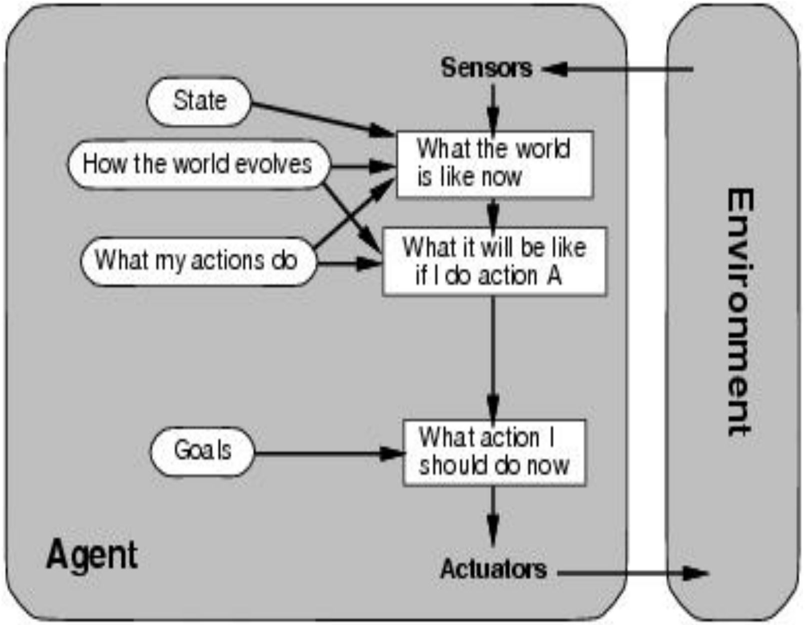
Agent types; reflex and state

```
function REFLEX-AGENT-WITH-STATE(percept) returns an action

    static: rules, a set of condition-action rules
            state, a description of the current world state
            action, the most recent action.

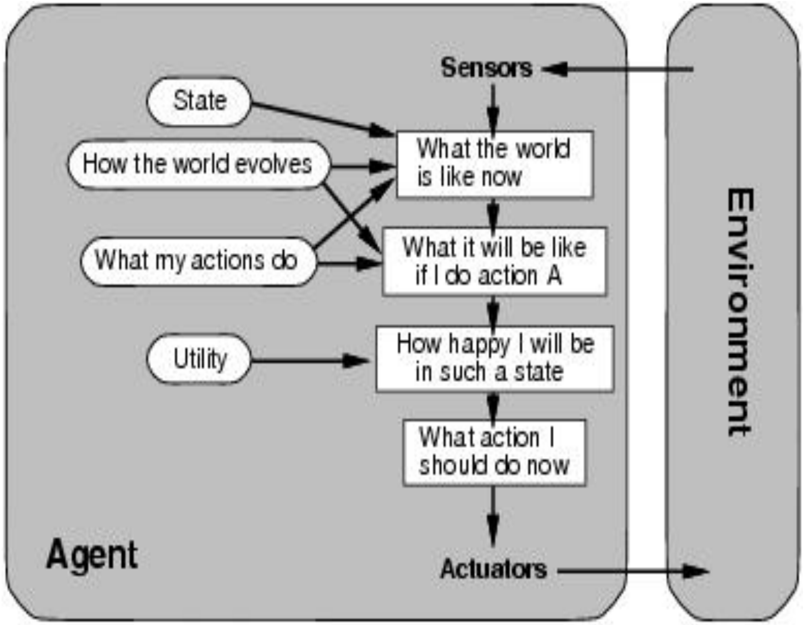
    state ← UPDATE-STATE(state, action, percept)
    rule ← RULE-MATCH(state, rule)
    action ← RULE-ACTION[rule]
    return action
```

Agent types; goal-based


Sensors
State
How the world evolves
What my actions do
What the world is like now
What it will be like if I do action A
Goals
What action I should do now
Agent
Actuators
Environment

- The agent needs a goal to know which situations are *desirable*.
  - Things become difficult when long sequences of actions are required to find the goal.
- Typically investigated in **search** and **planning** research.
- Major difference: future is taken into account
- Is more flexible since knowledge is represented explicitly and can be manipulated.

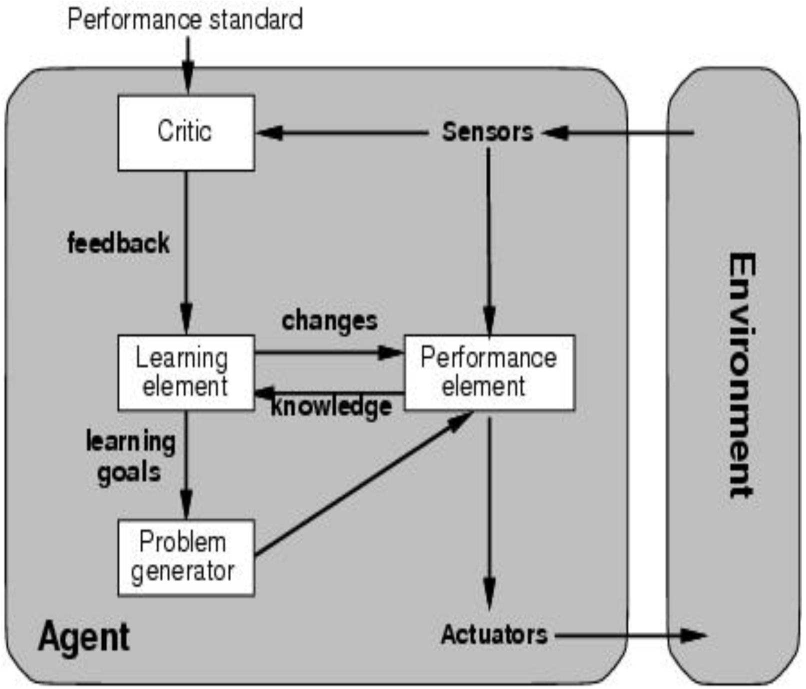
Agent types; utility-based



Sensors
State
How the world evolves
What my actions do
Utility
What the world is like now
What it will be like if I do action A
How happy I will be in such a state
What action I should do now
Agent
Actuators
Environment

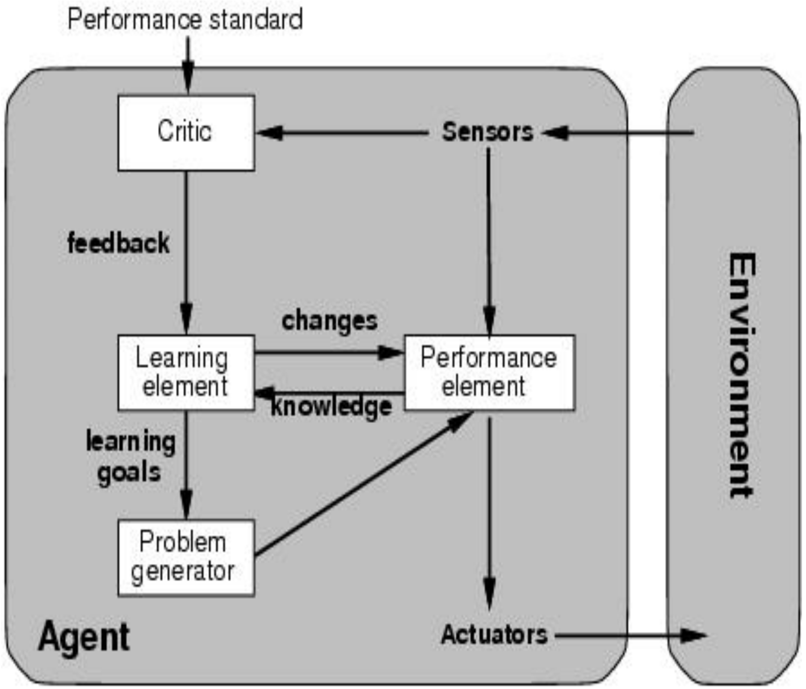
- Certain goals can be reached in different ways.
  - Some are better, have a higher utility.
- Utility function maps a (sequence of) state(s) onto a real number.
- Improves on goals:
  - Selecting between conflicting goals
  - Select appropriately between several goals based on likelihood of success.

Agent types; learning



- All previous agent-programs describe methods for selecting *actions*.
  - Yet it does not explain the origin of these programs.
  - Learning mechanisms can be used to perform this task.
  - Teach them instead of instructing them.
  - Advantage is the robustness of the program toward initially unknown environments.

Agent types; learning



- *Learning element*: introduce improvements in performance element.
  - Critic provides feedback on agents performance based on fixed performance standard.
- *Performance element*: selecting actions based on percepts.
  - Corresponds to the previous agent programs
- *Problem generator*: suggests actions that will lead to new and informative experiences.
  - Exploration vs. exploitation