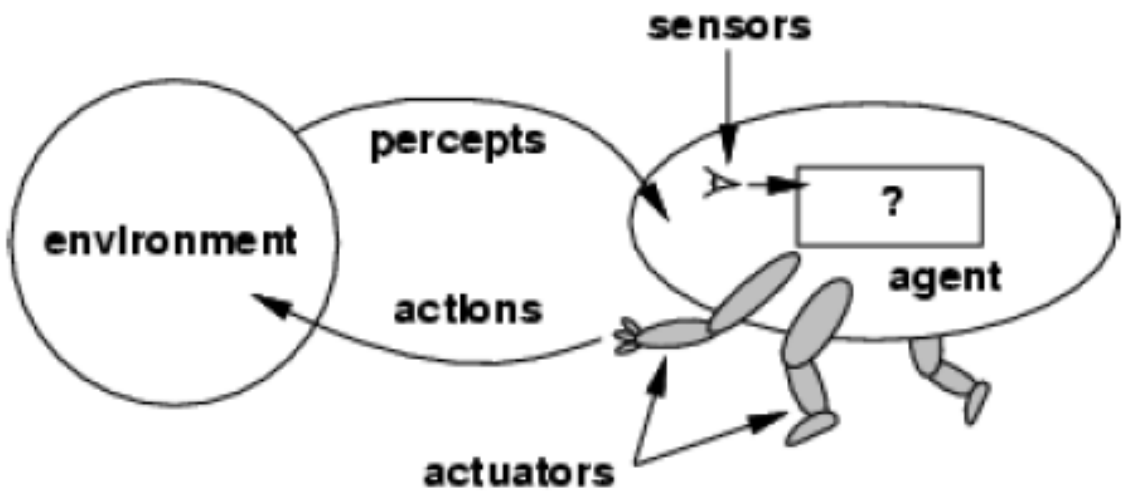
Agents

- An agent is anything that can be viewed as
  - perceiving its environment through sensors and
  - acting upon that environment through actuators
  - Assumption: Every agent can perceive its own actions (but not always the effects)



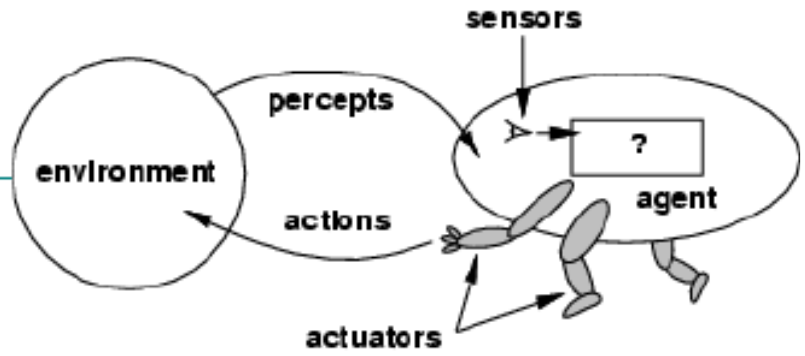
Agents

- Human agent:
  - eyes, ears, and other organs for sensors;
  - hands,legs, mouth, and other body parts for actuators

- Robotic agent:
  - cameras and infrared range finders for sensors;
  - various motors for actuators

- A software agent:
  - Keystrokes, file contents, received network packages as sensors
  - Displays on the screen, files, sent network packets as actuators

Agents and environments



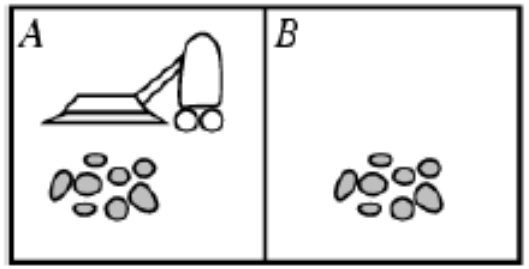
- Percept: agent's perceptual input at any given instant
- Percept sequence: complete history of everything the agent has ever perceived
- An agent's choice of action at any given instant can depend on the entire percept sequence observed to date

- An agent's behavior is described by the agent function which maps from percept histories to actions:

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

- We can imagine tabulating the agent function that describes any given agent (External characterization)
- Internally, the agent function will be implemented by an agent program which runs on the physical architecture to produce f
- agent = architecture + program

Vacuum-cleaner world



- Two locations: A and B
- Percepts: location and contents, e.g., [A,Dirty]
- Actions: *Left*, *Right*, *Suck*, *NoOp*

Percept sequence	Actions
[A,Clean]	Right
[A, Dirty]	Suck
[B,Clean]	Left
[B,Dirty]	Suck
[A,Clean],[A,Clean]	Right
[A,Clean],[A,Dirty]	Suck
…	…
[A,Clean],[A.Clean],[A,Clean]	Right
[A,Clean],[A,Clean],[A,Clean]	Suck

One simple function is :

if the current square is dirty then suck, otherwise move to the other square

Rational agents

- An agent should strive to "do the right thing", based on what it can perceive and the actions it can perform.
- The right action is the one that will cause the agent to be most successful
- Performance measure: An objective criterion for success of an agent's behavior
- E.g., performance measure of a vacuum-cleaner agent could be amount of dirt cleaned up, amount of time taken, amount of electricity consumed, amount of noise generated, etc.
- As a general rule, it is better to design performance measures according to what one actually wants in the environment. Rather than according to how one thinks the agent should behave (amount of dirt cleaned vs a clean floor)
- A more suitable measure would reward the agent for having a clean floor

What is rational at any given time depends on four things:

- The performance measure that defines the criterion of success.
- The agent's prior knowledge of the environment.
- The actions that the agent can perform.
- The agent's percept sequence to date.

Definition of a rational agent

For each possible percept sequence, a rational agent should select an action that is expected to maximize its performance measure, given the evidence provided by the percept sequence and whatever built-in knowledge the agent has.

Under the below circumstances, vacuum cleaner agent is rational!

- The performance measure awards one point for each clean square at each time step, over a “lifetime” of 1000 time steps.

• The “geography” of the environment is known *a priori* but the dirt distribution and the initial location of the agent are not. Clean squares stay clean and sucking cleans the current square.
The Left and Right actions move the agent left and right except when this would take the agent outside the environment, in which case the agent remains where it is.

• The only available actions are Left , Right, and Suck.

• The agent correctly perceives its location and whether that location contains dirt.

Vacuum cleaner agent

- Same agent would be irrational under different circumstances
  - once all dirt is cleaned up it will oscillate needlessly back and forth.
  - If the performance measure includes a penalty of one point for each movement left or right, the agent will fare poorly.
  - A better agent for this case would do nothing once it is sure that all the squares are clean.
  - If the clean squares can become dirty again, the agent should occasionally check and clean them if needed.
  - If the geography of the environment is unknown the agent will need to explore it rather than stick to squares A and B

Rational agents

- Rationality is distinct from omniscience (all-knowing with infinite knowledge)
- Rationality maximizes expected performance while perfection maximizes actual performance
- Agents can perform actions in order to modify future percepts so as to obtain useful information (information gathering, exploration)
- An agent is autonomous if its behavior is determined by its own experience (with ability to learn and adapt)

Specifying the task environment (PEAS)

- PEAS:
  - **P**erformance measure,
  - **E**nvironment,
  - **A**ctuators,
  - **S**ensors
- In designing an agent, the first step must always be to specify the task environment (PEAS) as fully as possible

PEAS description for an automated taxi driver

Agent Type	Performance Measure	Environment	Actuators	Sensors
Taxi driver	Safe, fast, legal, comfortable trip, maximize profits	Roads, other traffic, pedestrians, customers	Steering, accelerator, brake, signal, horn, display	Cameras, sonar, speedometer, GPS, odometer, accelerometer, engine sensors, keyboard

Examples of agent types and their PEAS description

Agent Type	Performance Measure	Environment	Actuators	Sensors
Medical diagnosis system	Healthy patient, reduced costs	Patient, hospital, staff	Display of questions, tests, diagnoses, treatments, referrals	Keyboard entry of symptoms, findings, patient's answers
Satellite image analysis system	Correct image categorization	Downlink from orbiting satellite	Display of scene categorization	Color pixel arrays
Part-picking robot	Percentage of parts in correct bins	Conveyor belt with parts; bins	Jointed arm and hand	Camera, joint angle sensors
Refinery controller	Purity, yield, safety	Refinery, operators	Valves, pumps, heaters, displays	Temperature, pressure, chemical sensors
Interactive English tutor	Student's score on test	Set of students, testing agency	Display of exercises, suggestions, corrections	Keyboard entry

Environment types

- Fully observable vs. partially observable
- Deterministic vs. stochastic
- Episodic vs. sequential
- Static vs. dynamic
- Discrete vs. continuous
- Single agent vs. multiagent

Environment types

Fully observable vs. partially observable:

- An environment is fully observable if an agent's sensors give it access to the complete state of the environment at each point in time.
- Fully observable environments are convenient, because the agent need not maintain any internal state to keep track of the world
- An environment might be partially observable because of noisy and inaccurate sensors or because parts of the state are simply missing from the sensor data
- Examples: vacuum cleaner with local dirt sensor, taxi driver

Environment types

Deterministic vs. stochastic:

- The environment is deterministic if the next state of the environment is completely determined by the current state and the action executed by the agent.
- In principle, an agent need not worry about uncertainty in a fully observable, deterministic environment
- If the environment is partially observable then it could appear to be stochastic
- Examples: Vacuum world is deterministic while taxi driver is not
- If the environment is deterministic except for the actions of other agents, then the environment is strategic

Environment types

Episodic vs. sequential:

- In episodic environments, the agent's experience is divided into atomic "episodes" (each episode consists of the agent perceiving and then performing a single action), and the choice of action in each episode depends only on the episode itself.
- Examples: classification tasks

- In sequential environments, the current decision could affect all future decisions
- Examples: chess and taxi driver

Environment types

Static vs. dynamic:

- The environment is unchanged while an agent is deliberating.
- Static environments are easy to deal with because the agent need not keep looking at the world while it is deciding on the action or need it worry about the passage of time
- Dynamic environments continuously ask the agent what it wants to do
- The environment is semi-dynamic if the environment itself does not change with the passage of time but the agent's performance score does
- Examples: taxi driving is dynamic, chess when played with a clock is semi-dynamic, crossword puzzles are static

Environment types

Discrete vs. continuous:

- A limited number of distinct, clearly defined states, percepts and actions.
- Examples: Chess has finite number of discrete states, and has discrete set of percepts and actions. Taxi driving has continuous states, and actions

Environment types

Single agent vs. multiagent:

- An agent operating by itself in an environment is single agent
- Examples: Crossword is a single agent while chess is two-agents
- Question: Does an agent A have to treat an object B as an agent or can it be treated as a stochastically behaving object
- Whether B's behaviour is best described by as maximizing a performance measure whose value depends on agent's A behaviour
- Examples: chess is a competitive multiagent environment while taxi driving is a partially cooperative multiagent environment

Task Environment	Observable	Agents	Deterministic	Episodic	Static	Discrete
Crossword puzzle	Fully	Single	Deterministic	Sequential	Static	Discrete
Chess with a clock	Fully	Multi	Deterministic	Sequential	Semi	Discrete
Poker	Partially	Multi	Stochastic	Sequential	Static	Discrete
Backgammon	Fully	Multi	Stochastic	Sequential	Static	Discrete
Taxi driving	Partially	Multi	Stochastic	Sequential	Dynamic	Continuous
Medical diagnosis	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
Image analysis	Fully	Single	Deterministic	Episodic	Semi	Continuous
Part-picking robot	Partially	Single	Stochastic	Episodic	Dynamic	Continuous
Refinery controller	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
Interactive English tutor	Partially	Multi	Stochastic	Sequential	Dynamic	Discrete

- The environment type largely determines the agent design
- The real world is (of course) partially observable, stochastic, sequential, dynamic, continuous, multi-agent

Agent functions and programs

- An agent is completely specified by the agent function mapping percept sequences to actions
- One agent function (or a small equivalence class) is rational
- Aim: find a way to implement the rational agent function concisely -> design an **agent program**

Agent = agent program + architecture

- Architecture: some sort of computing device with physical sensors and actuators (PC, robotic car)
  - should be appropriate: walk action requires legs

Agent functions and programs

- Agent program:
  - Takes the current percept as input from the sensors
  - Return an action to the actuators

  - While agent function takes the whole percept history, agent program takes just the current percept as input which the only available input from the environment
  - The agent need to remember the whole percept sequence, if it needs it

Table-lookup agent

- A trivial agent program: keeps track of the percept sequence and then uses it to index into a table of actions to decide what to do
- The designers must construct the table that contains the appropriate action for every possible percept sequence

```
function TABLE-DRIVEN-AGENT(percept) returns an action
    static:  percepts, a sequence, initially empty
             table, a table of actions, indexed by percept sequences, initially fully specified
    append percept to the end of percepts
    action <--LOOKUP(percepts, table)
    return action
```

- Drawbacks:
  - Huge table (P^T , P: set of possible percepts, T: lifetime)
    - Space to store the table
    - Take a long time to build the table
    - No autonomy
    - Even with learning, need a long time to learn the table entries

Agent types

- Rather than a table how we can produce rational behavior from a small amount of code
-
- Four basic types in order of increasing generality:
  - Simple reflex agents
  - Model-based reflex agents
  - Goal-based agents
  - Utility-based agents

Simple reflex agents

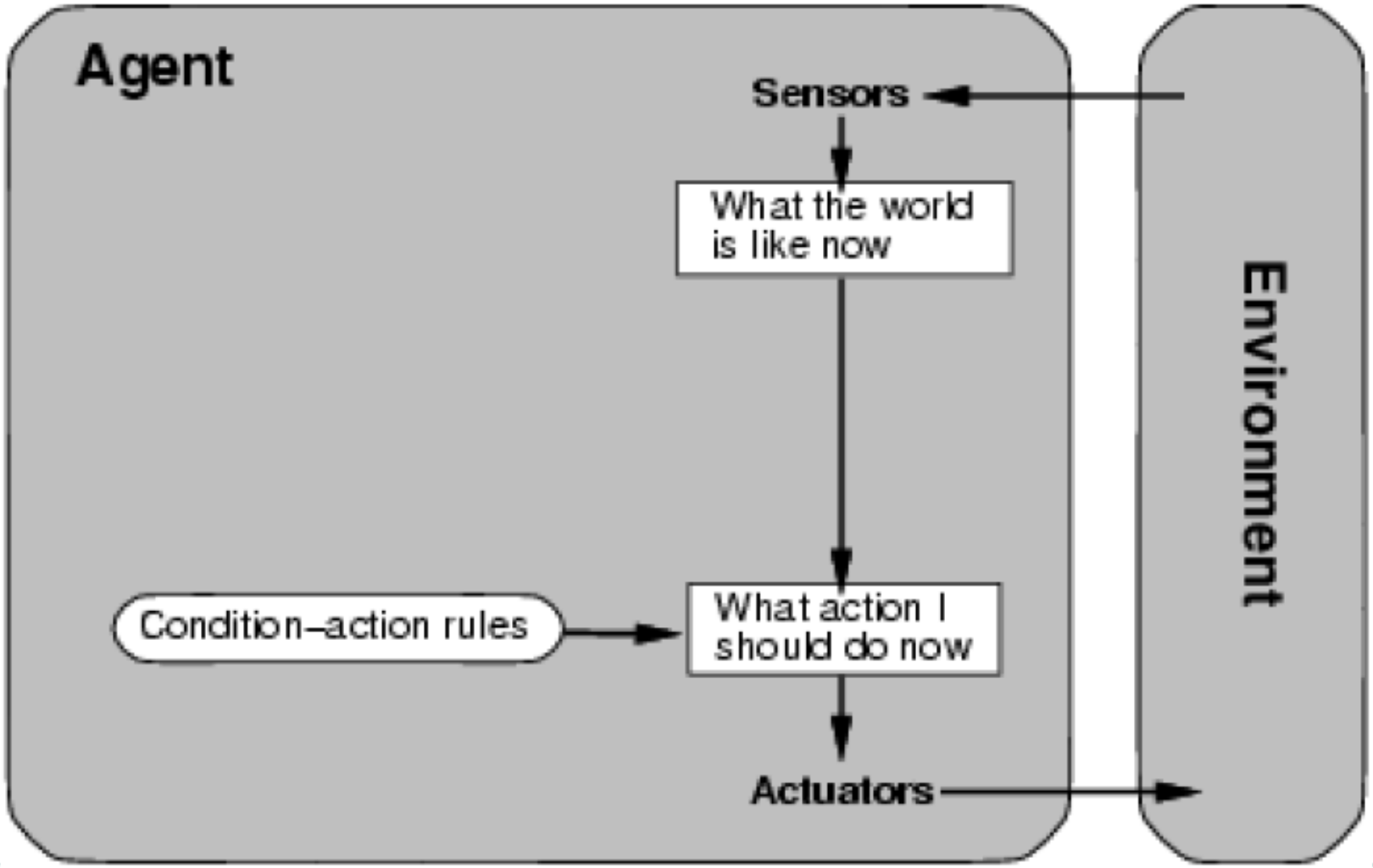
- Select actions on the basis of the **current percept** ignoring the rest of the percept history

- Example: simple reflex vacuum cleaner agent

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

- **Condition-action-rule**
- Example: **if** *car-in-front-is-breaking* **then** *initiate-breaking*

Simple reflex agents



Simple reflex agents

```
function SIMPLE-REFLEX-AGENT(percept) returns an action
    static: rules,  a set if condition-action rules
    state <-- INTERPRET_INPUT(percept)
    rule <-- RULE_MATCH(state, rules)
    action <-- RULE_ACTION[rule]
    return action
```

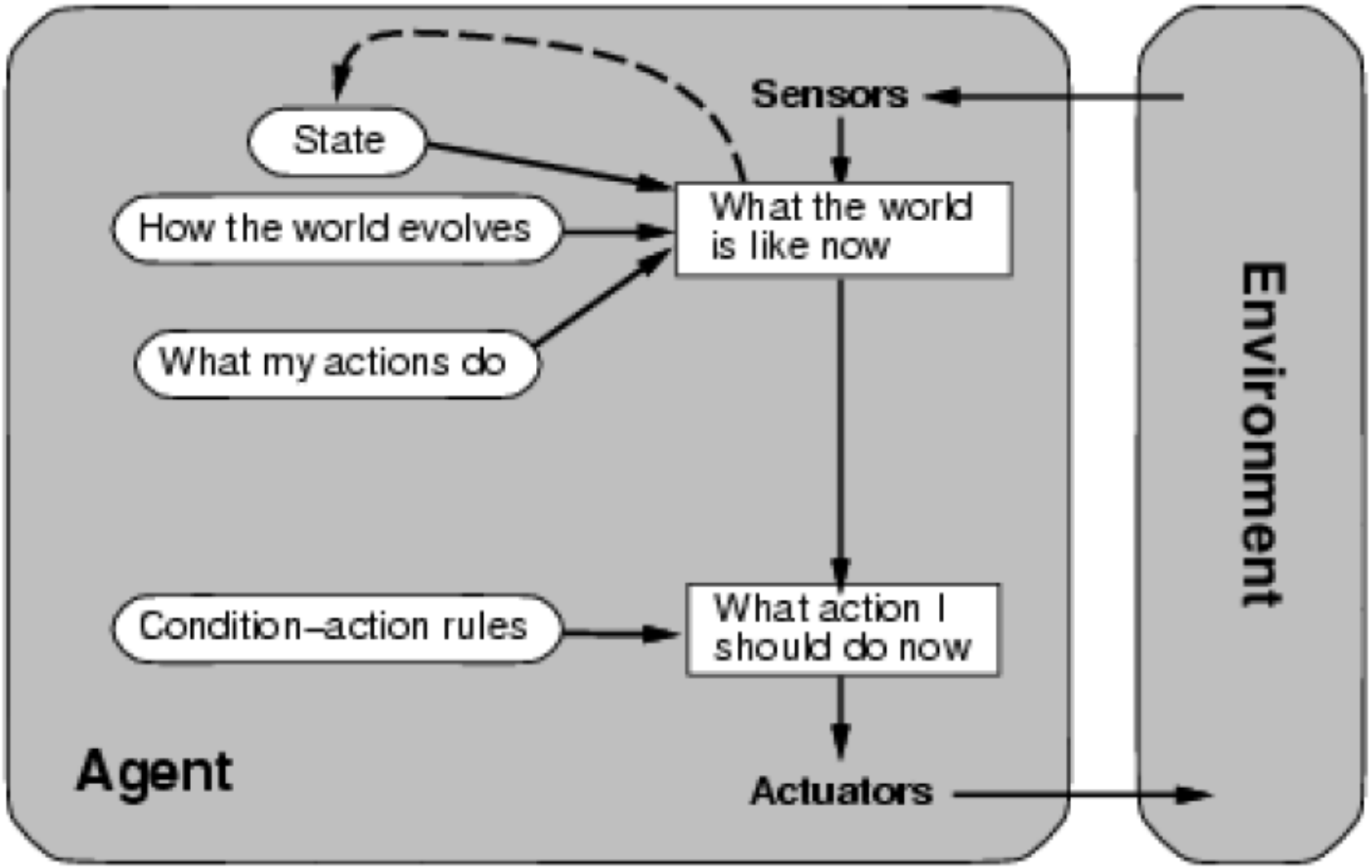
- Simple-reflex agents are simple, but they turn out to be of very limited intelligence
- The agent will work only if the correct decision can be made on the basis of the current percept – that is only if the environment is fully observable
- Infinite loops are often unavoidable – escape could be possible by randomizing

Model-based reflex agents

- The agent should keep track of the part of the world it can't see now
- The agent should maintain some sort of internal state that depends on the percept history and reflects at least some of the unobserved aspects of the current state
- Updating the internal state information as time goes by requires two kinds of knowledge to be encoded in the agent program
  - Information about how the world evolves independently of the agent
  - Information about how the agent's own actions affects the world

- Model of the world – model based agents

Model-based reflex agents



Model-based reflex agents

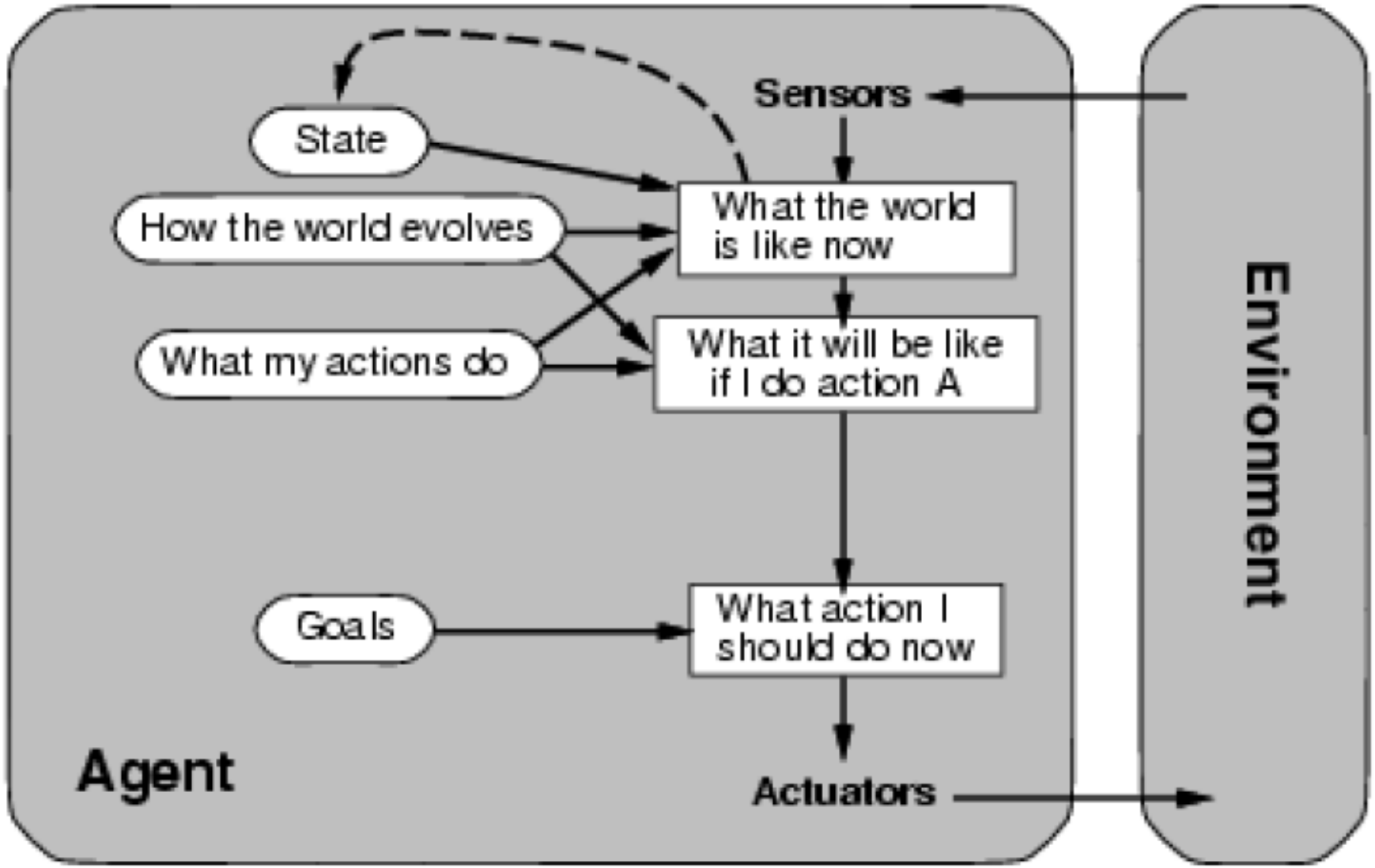
```
function REFLEX-AGENT-WITH-STATE(percept) returns an action
    static:  state,  a description of the current world state
             rules,  a set of condition-action rules
             action, the most recent action, initially none

    state <-- UPDATE_INPUT(state, action, percept)
    rule <-- RULE_MATCH(state, rules)
    action <-- RULE_ACTION[rule]
    return action
```

Goal-based agents

- Knowing about the current state of the environment is not always enough to decide what to do (e.g. decision at a road junction)
- The agent needs some sort of goal information that describes situations that are desirable
- The agent program can combine this with information about the results of possible actions in order to choose actions that achieve the goal
- Usually requires search and planning

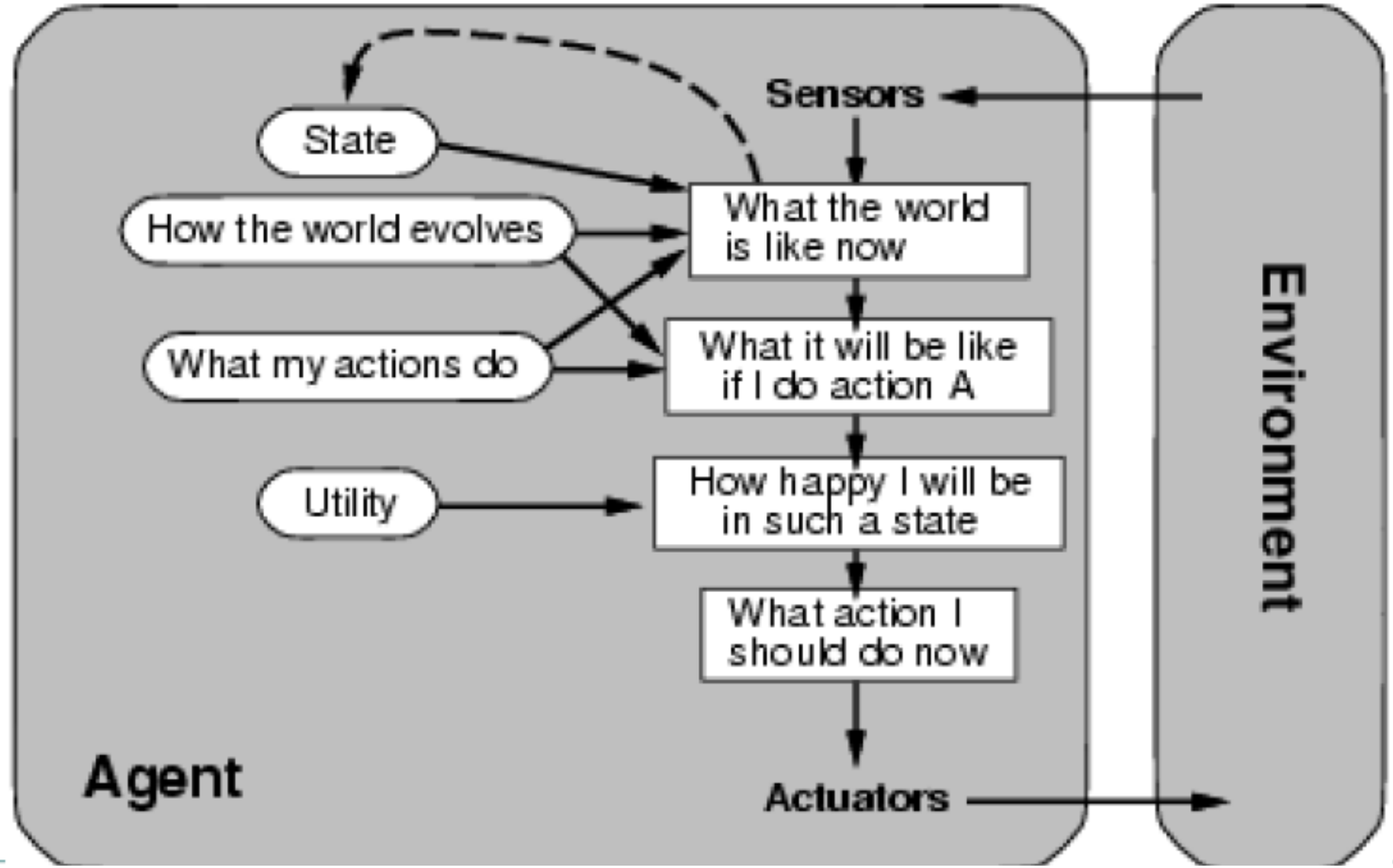
Goal-based agents



Utility-based agents

- Goals alone are not really enough to generate high quality behavior in most environments – they just provide a binary distinction between happy and unhappy states
- A more general performance measure should allow a comparison of different world states according to exactly how happy they would make the agent if they could be achieved
- Happy – Utility (the quality of being useful)
- A utility function maps a state onto a real number which describes the associated degree of happiness

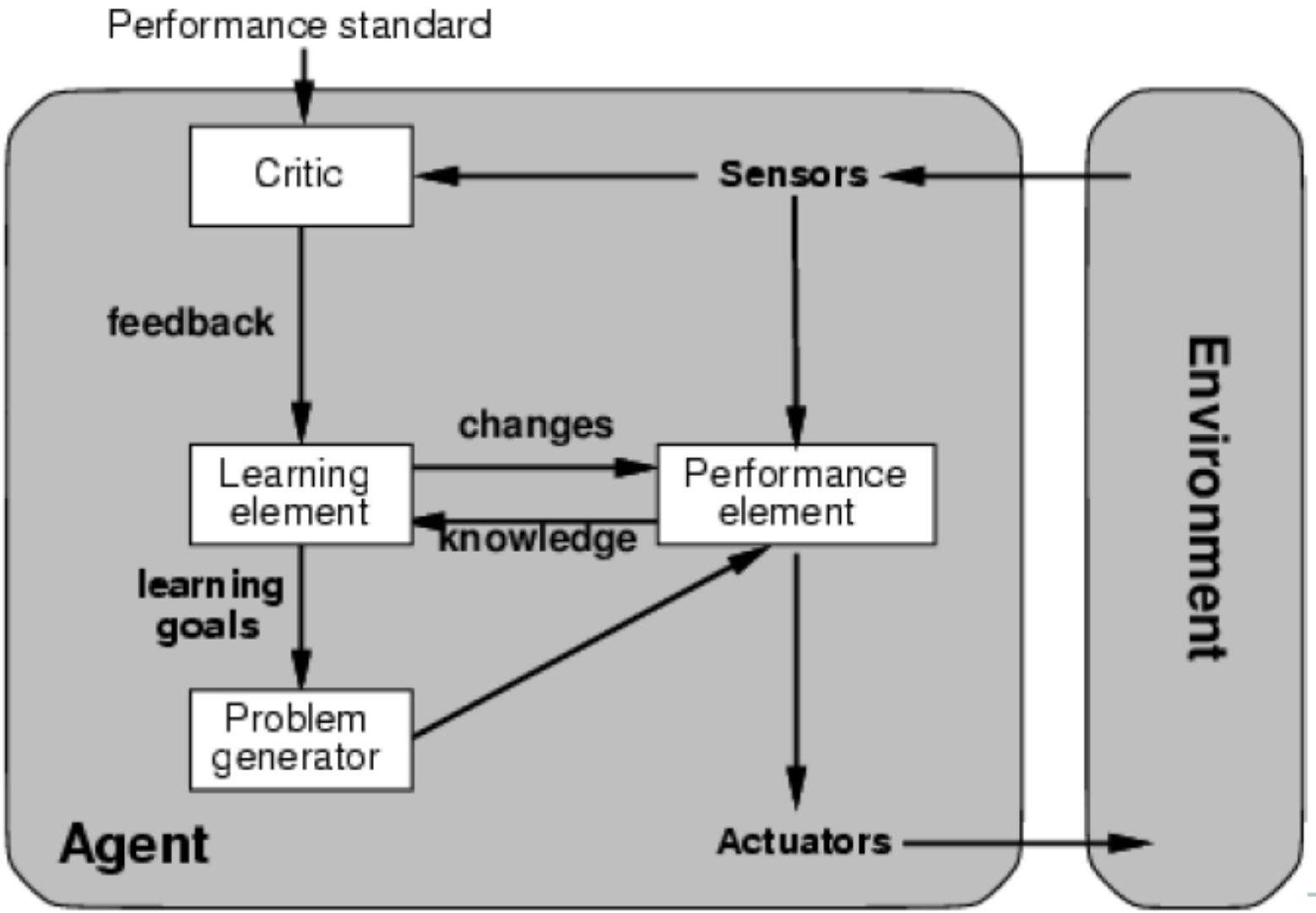
Utility-based agents



Learning agents

- Turing – instead of actually programming intelligent machines by hand, which is too much work, build learning machines and then teach them
- Learning also allows the agent to operate in initially unknown environments and to become more competent than its initial knowledge alone might allow

Learning agents



Learning agents

- Learning element – responsible for making improvements
- Performance element – responsible for selecting external actions (it is what we had defined as the entire agent before)
- Learning element uses feedback from the critic on how the agent is doing and determines how the performance element should be modified to do better in the future
- Problem generator is responsible for suggesting actions that will lead to a new and informative experiences