CS5010
Artificial Intelligence Principles:
Lecture 3

Artificial Intelligence

Chapter 1

Annotations by Tom Kelsey look like this

The slides were written by Russell & Norvig for their course based on Artificial Intelligence: A Modern Approach

I have the 3rd Edition Global Edition

If I refer to a section number, yours might be slightly different

Outline

- ♢ What is AI?
- ♢ A brief history
- ♢ The state of the art

Much of this is reinforcement of
Lectures 1 & 2 in Week 1

What is AI?

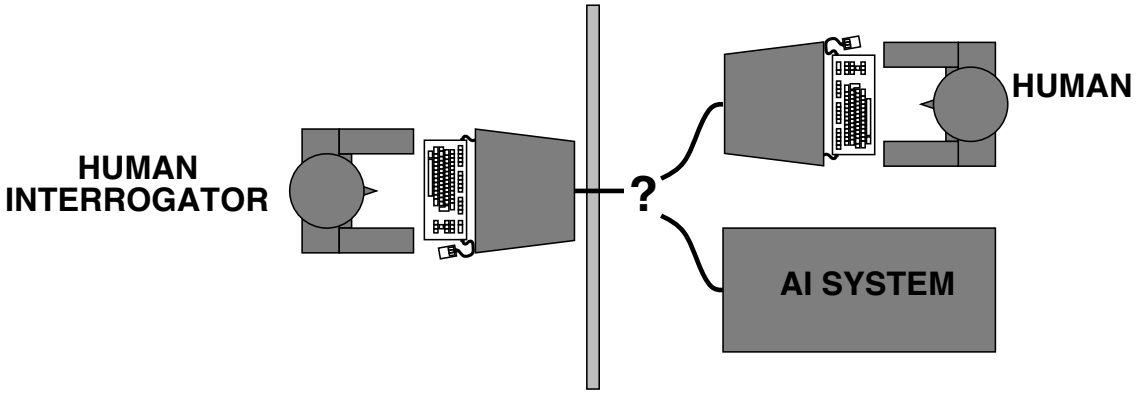
Systems that think like humans	**Systems that think rationally**
Systems that act like humans	**Systems that act rationally**

Acting humanly: The Turing test

Turing (1950) "Computing machinery and intelligence":

♢ "Can machines think?" ⟶ "Can machines behave intelligently?"

♢ Operational test for intelligent behavior: the Imitation Game



♢ Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes

♢ Anticipated all major arguments against AI in following 50 years

♢ Suggested major components of AI: knowledge, reasoning, language understanding, learning

Problem: Turing test is not **reproducible**, **constructive**, or amenable to **mathematical analysis**

Thinking humanly: Cognitive Science

1960s "cognitive revolution": information-processing psychology replaced prevailing orthodoxy of behaviorism

Requires scientific theories of internal activities of the brain

- What level of abstraction? "Knowledge" or "circuits"?
- How to validate? Requires
  1) Predicting and testing behavior of human subjects (top-down)
  or 2) Direct identification from neurological data (bottom-up)

Both approaches (roughly, Cognitive Science and Cognitive Neuroscience) are now distinct from AI

Both share with AI the following characteristic:

the available theories do not explain (or engender) anything resembling human-level general intelligence

Hence, all three fields share one principal direction!

Thinking rationally: Laws of Thought

Normative (or prescriptive) rather than descriptive

Aristotle: what are correct arguments/thought processes?

Several Greek schools developed various forms of logic:
notation and **rules of derivation** for thoughts;
may or may not have proceeded to the idea of mechanization

Direct line through mathematics and philosophy to modern AI

Problems:
1) Not all intelligent behavior is mediated by logical deliberation
2) What is the purpose of thinking? What thoughts **should** I have out of all the thoughts (logical or otherwise) that I **could** have?

In philosophy, normative statements make claims about how things should or ought to be, how to value them, which things are good or bad, and which actions are right or wrong.

Acting rationally

Rational behavior: doing the right thing

The right thing: that which is expected to maximize goal achievement, given the available information

Doesn't necessarily involve thinking—e.g., blinking reflex—but thinking should be in the service of rational action

Aristotle (Nicomachean Ethics):

> **Every art and every inquiry, and similarly every action and pursuit, is thought to aim at some good**

Rational agents

An agent is an entity that perceives and acts

This course is about designing rational agents

Abstractly, an agent is a function from percept histories to actions:

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

For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance

Caveat: **computational limitations make perfect rationality unachievable**

$\rightarrow$ design best program for given machine resources

AI prehistory

Philosophy	logic, methods of reasoning
	mind as physical system
	foundations of learning, language, rationality
Mathematics	formal representation and proof
	algorithms, computation, (un)decidability, (in)tractability
	probability
Psychology	adaptation
	phenomena of perception and motor control
	experimental techniques (psychophysics, etc.)
Economics	formal theory of rational decisions
Linguistics	knowledge representation
	grammar
Neuroscience	plastic physical substrate for mental activity
Control theory	homeostatic systems, stability
	simple optimal agent designs

Potted history of AI

1943	McCulloch & Pitts: Boolean circuit model of brain
1950	Turing's "Computing Machinery and Intelligence"
1952–69	Look, Ma, no hands!
1950s	Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
1956	Dartmouth meeting: "Artificial Intelligence" adopted
1965	Robinson's complete algorithm for logical reasoning
1966–74	AI discovers computational complexity Neural network research almost disappears
1969–79	Early development of knowledge-based systems
1980–88	Expert systems industry booms
1988–93	Expert systems industry busts: "AI Winter"
1985–95	Neural networks return to popularity
1988–	Resurgence of probability; general increase in technical depth "Nouvelle AI": ALife, GAs, soft computing
1995–	Agents, agents, everywhere . . .
2003–	Human-level AI back on the agenda

State of the art

Which of the following can be done at present?

♢ Play a decent game of table tennis

State of the art

Which of the following can be done at present?

- ♢ Play a decent game of table tennis
- ♢ Drive safely along a curving mountain road

State of the art

Which of the following can be done at present?

- ♢ Play a decent game of table tennis
- ♢ Drive safely along a curving mountain road
- ♢ Drive safely along Telegraph Avenue

See the media file on studres

Self driving AI has advanced significantly recently

State of the art

Which of the following can be done at present?

- ♢ Play a decent game of table tennis
- ♢ Drive safely along a curving mountain road
- ♢ Drive safely along Telegraph Avenue
- ♢ Buy a week's worth of groceries on the web

State of the art

Which of the following can be done at present?

- ♢ Play a decent game of table tennis
- ♢ Drive safely along a curving mountain road
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- ♢ Buy a week's worth of groceries on the web
- ♢ Buy a week's worth of groceries at Berkeley Bowl

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- ♢ Drive safely along a curving mountain road
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- ♢ Play a decent game of bridge

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- ♢ Buy a week's worth of groceries on the web
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- ♢ Play a decent game of bridge
- ♢ Discover and prove a new mathematical theorem

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- ♢ Play a decent game of bridge
- ♢ Discover and prove a new mathematical theorem
- ♢ Design and execute a research program in molecular biology

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- ♢ Play a decent game of bridge
- ♢ Discover and prove a new mathematical theorem
- ♢ Design and execute a research program in molecular biology
- ♢ Write an intentionally funny story

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- ♢ Discover and prove a new mathematical theorem
- ♢ Design and execute a research program in molecular biology
- ♢ Write an intentionally funny story
- ♢ Give competent legal advice in a specialized area of law

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- ♢ Write an intentionally funny story
- ♢ Give competent legal advice in a specialized area of law
- ♢ Translate spoken English into spoken Swedish in real time

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- ♢ Converse successfully with another person for an hour

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- ♢ Converse successfully with another person for an hour
- ♢ Perform a complex surgical operation

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- ♢ Translate spoken English into spoken Swedish in real time
- ♢ Converse successfully with another person for an hour
- ♢ Perform a complex surgical operation
- ♢ Unload any dishwasher and put everything away

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- ♢ Unload any dishwasher and put everything away

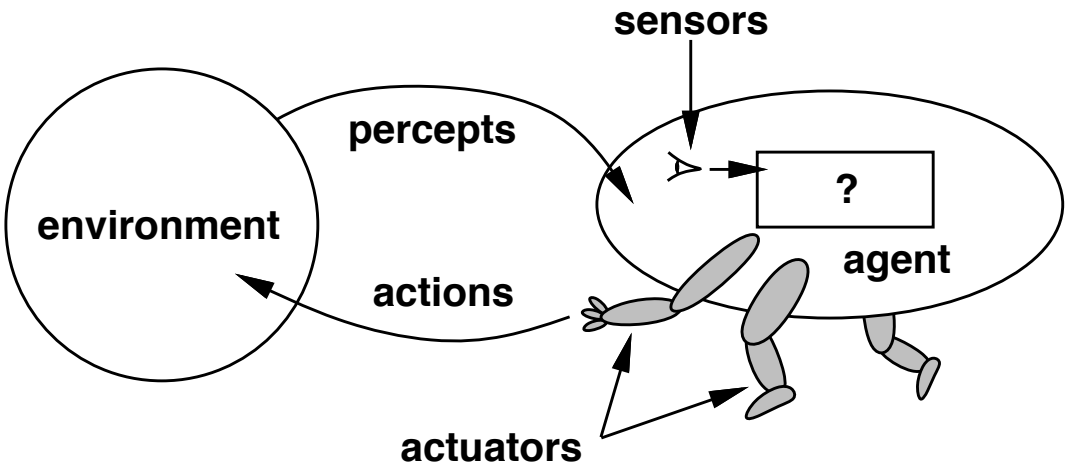
Intelligent Agents

Chapter 2

Outline

- ♢ Agents and environments
- ♢ Rationality
- ♢ PEAS (Performance measure, Environment, Actuators, Sensors)
- ♢ Environment types
- ♢ Agent types

Agents and environments



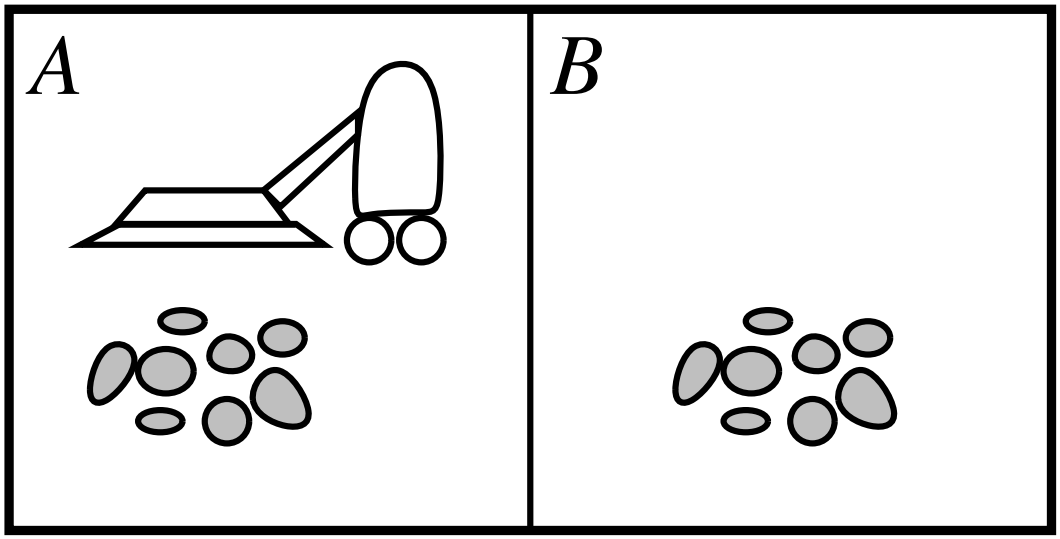
Agents include humans, robots, softbots, thermostats, etc.

The agent function maps from percept histories to actions:

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

The agent program runs on the physical architecture to produce f

Vacuum-cleaner world



Percepts: location and contents, e.g., $[A, Dirty]$

Actions: $Left$, $Right$, $Suck$, $NoOp$

A vacuum-cleaner agent

Percept sequence	Action
$[A, Clean]$	$Right$
$[A, Dirty]$	$Suck$
$[B, Clean]$	$Left$
$[B, Dirty]$	$Suck$
$[A, Clean], [A, Clean]$	$Right$
$[A, Clean], [A, Dirty]$	$Suck$
⋮	⋮

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** $Left$

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

What is a correct
or suitable function?

Rationality

Fixed performance measure evaluates the environment sequence

- one point per square cleaned up in time T?
- one point per clean square per time step, minus one per move?
- penalize for $> k$ dirty squares?

A rational agent chooses whichever action maximizes the expected value of the performance measure given the percept sequence to date

Rational $\neq$ omniscient

- percepts may not supply all relevant information

Rational $\neq$ clairvoyant

- action outcomes may not be as expected

Hence, rational $\neq$ successful

Rational $\Rightarrow$ exploration, learning, autonomy

PEAS

To design a rational agent, we must specify the task environment

Consider, e.g., the task of designing an automated taxi:

Performance measure??

Environment??

Actuators??

Sensors??

PEAS

To design a rational agent, we must specify the task environment

Consider, e.g., the task of designing an automated taxi:

Performance measure?? safety, destination, profits, legality, comfort, . . .

Environment?? US streets/freeways, traffic, pedestrians, weather, . . .

Actuators?? steering, accelerator, brake, horn, speaker/display, . . .

Sensors?? video, accelerometers, gauges, engine sensors, keyboard, GPS, . . .

Internet shopping agent

Performance measure??

Environment??

Actuators??

Sensors??

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?? HTML pages (text, graphics, scripts)

Environment types

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

Environment types

	Solitaire	Backgammon	Internet shopping	Taxi
Observable??	Yes	Yes	No	No
Deterministic??				
Episodic??				
Static??				
Discrete??				
Single-agent??				

Observable means that the sensors give access to the complete state at every action. If not, then partially observable

Environment types

	Solitaire	Backgammon	Internet shopping	Taxi
Observable??	Yes	Yes	No	No
Deterministic??	Yes	No	Partly	No
Episodic??				
Static??				
Discrete??				
Single-agent??				

Deterministic means that the current state and a chosen action completely specify the next state.
If not deterministic, then stochastic

Environment types

	Solitaire	Backgammon	Internet shopping	Taxi
Observable??	Yes	Yes	No	No
Deterministic??	Yes	No	Partly	No
Episodic??	No	No	No	No
Static??				
Discrete??				
Single-agent??				

Episodic means divided into discrete episodes, so that actions don't depend on event history. If not episodic, then sequential

This is unusual - much of AI is about using event history to inform future decisions

Environment types

	Solitaire	Backgammon	Internet shopping	Taxi
Observable??	Yes	Yes	No	No
Deterministic??	Yes	No	Partly	No
Episodic??	No	No	No	No
Static??	Yes	Semi	Semi	No
Discrete??				
Single-agent??				

Static means that the environment doesn't change while the agent is "thinking". Otherwise dynamic

Environment types

	Solitaire	Backgammon	Internet shopping	Taxi
Observable??	Yes	Yes	No	No
Deterministic??	Yes	No	Partly	No
Episodic??	No	No	No	No
Static??	Yes	Semi	Semi	No
Discrete??	Yes	Yes	Yes	No
Single-agent??				

Discrete and continuous are options for how percepts and actions of the agent vary over time

Accelerator precepts are continuous in the taxi example, as are braking actions

Environment types

	Solitaire	Backgammon	Internet shopping	Taxi
Observable??	Yes	Yes	No	No
Deterministic??	Yes	No	Partly	No
Episodic??	No	No	No	No
Static??	Yes	Semi	Semi	No
Discrete??	Yes	Yes	Yes	No
Single-agent??	Yes	No	Yes (except auctions)	No

The environment type largely determines the agent design

The real world is (of course) partially observable, stochastic, sequential, dynamic, continuous, multi-agent

Single-agent is not just counting the agents. Does agent A have to treat object B as another agent, or as an object with related sensor data? If not single-agent, do they cooperate or compete? Is agent A required or advised to respect the action decisions of agent B?

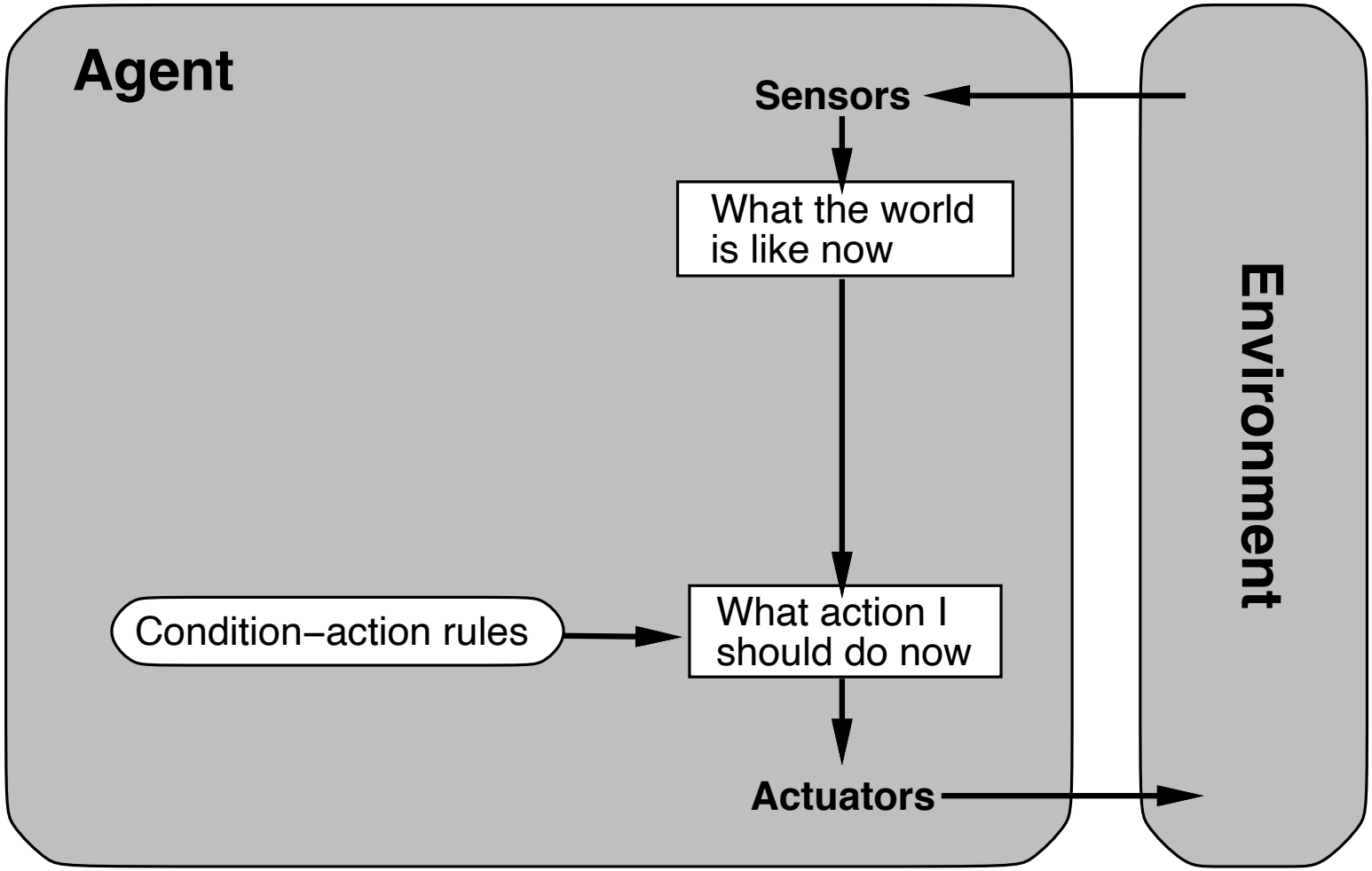
Agent types

Four basic types in order of increasing generality:

- simple reflex agents
- reflex agents with state
- goal-based agents
- utility-based agents

All these can be turned into learning agents

Simple reflex agents



Example

function REFLEX-VACUUM-AGENT([*location*,*status*]) **returns** an action

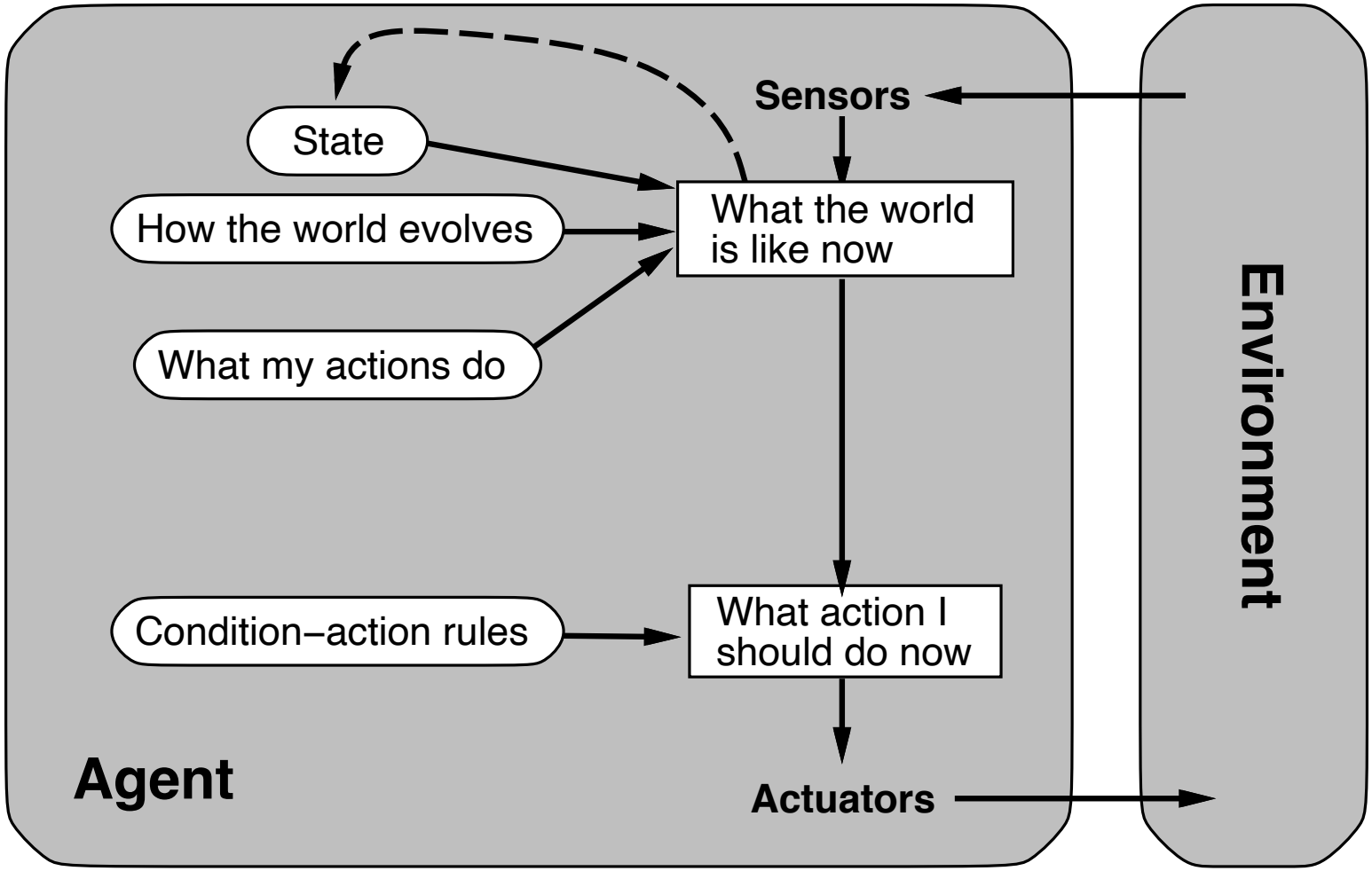
if *status* = *Dirty* **then return** *Suck*
else if *location* = *A* **then return** *Right*
else if *location* = *B* **then return** *Left*

```
(setq joe (make-agent :name 'joe :body (make-agent-body)
                      :program (make-reflex-vacuum-agent-program))

(defun make-reflex-vacuum-agent-program ()
  #'(lambda (percept)
      (let ((location (first percept)) (status (second percept)))
        (cond ((eq status 'dirty) 'Suck)
              ((eq location 'A) 'Right)
              ((eq location 'B) 'Left)))))
```

This code is LISP. Closely associated with the AI research community. All code & data are expressions which are evaluated to values. Each value can be any data type.
You do not need to learn LISP.

Reflex agents with state



Example

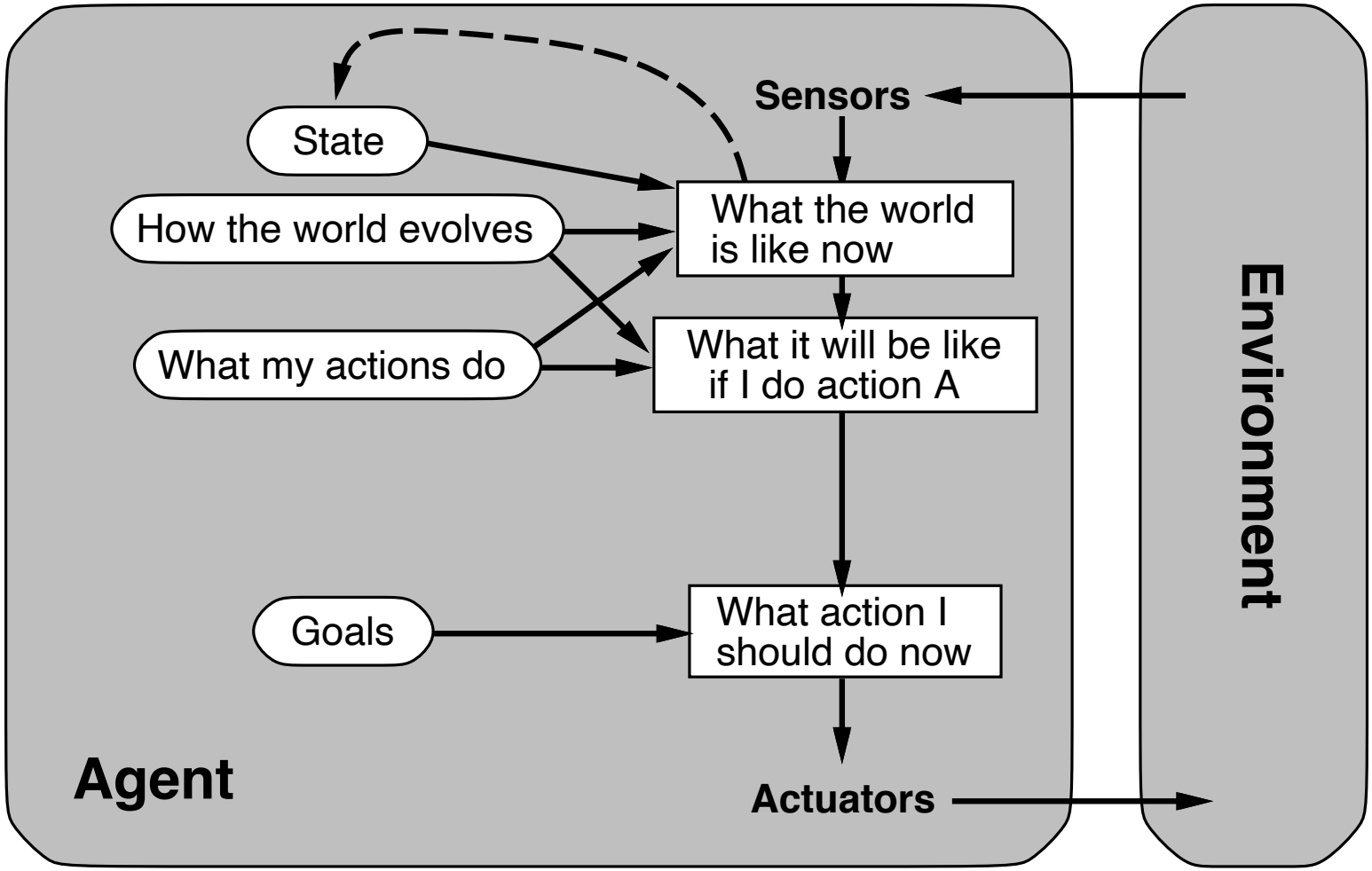
function REFLEX-VACUUM-AGENT([*location*,*status*]) **returns** an action
static: *last_A*, *last_B*, numbers, initially ∞

if *status* = *Dirty* **then** ...

```
(defun make-reflex-vacuum-agent-with-state-program ()
  (let ((last-A infinity) (last-B infinity))
  #'(lambda (percept)
      (let ((location (first percept)) (status (second percept)))
        (incf last-A) (incf last-B)
        (cond
         ((eq status 'dirty)
          (if (eq location 'A) (setq last-A 0) (setq last-B 0))
          'Suck)
         ((eq location 'A) (if (> last-B 3) 'Right 'NoOp))
         ((eq location 'B) (if (> last-A 3) 'Left 'NoOp)))))))
```

Keep track of the current state of the world, using an internal model.
Then choose an action using the reflex conditions

Goal-based agents



Keep track of both world state and goals. Choose an action that will (eventually) achieve the goals

Writing pseudocode for this is an exercise [2.7]

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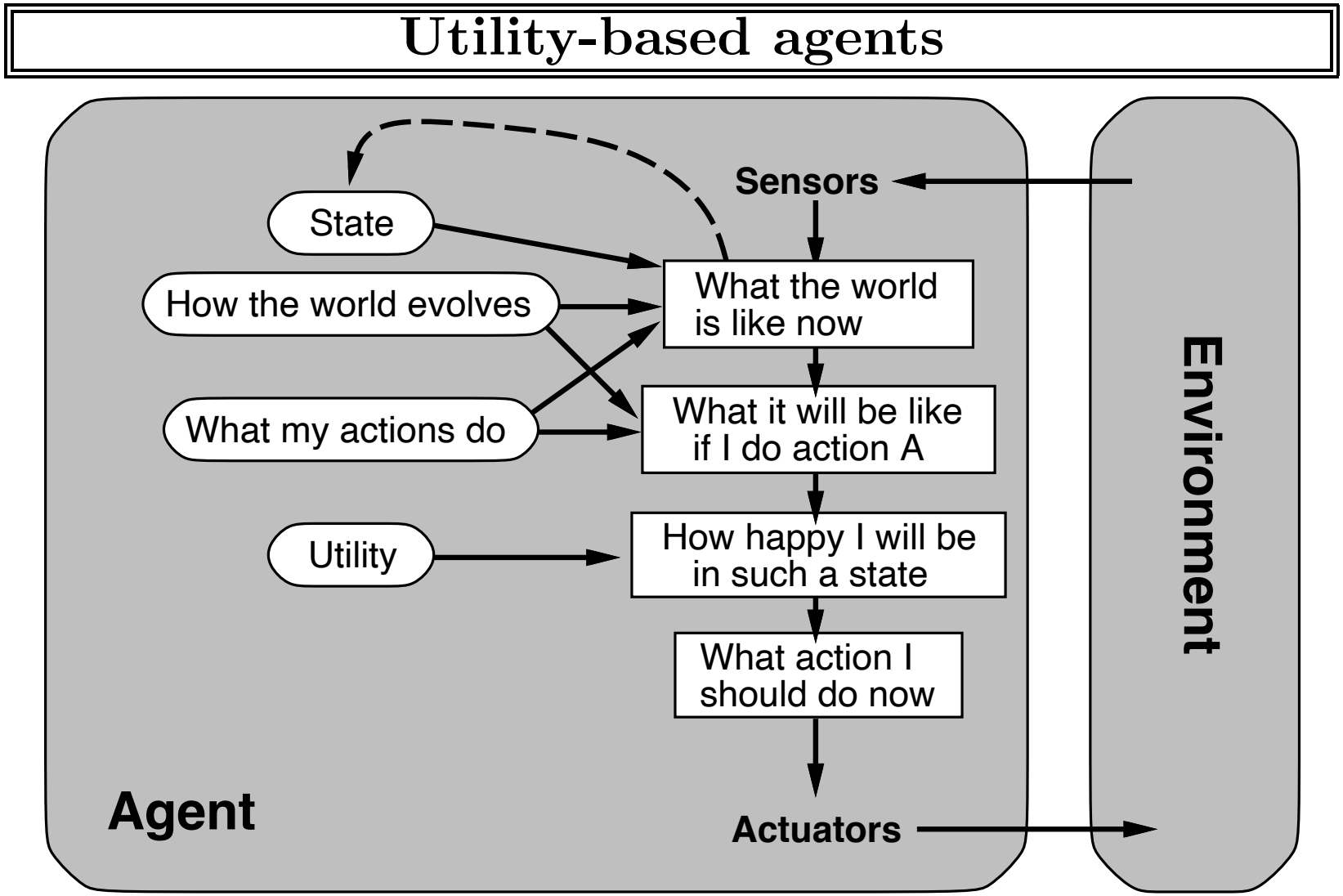
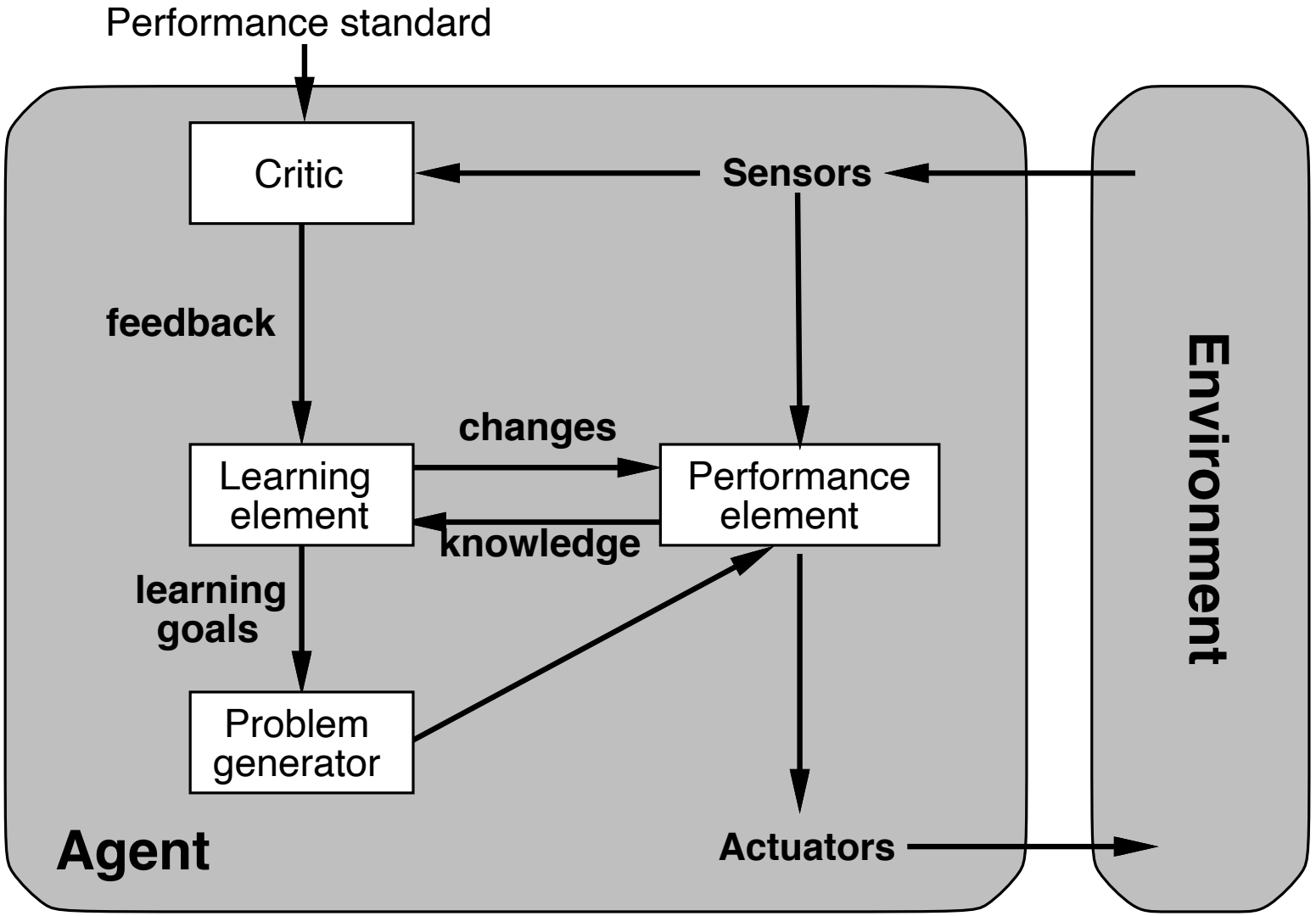


Utility is a measure of good/bad; happy/unhappy; rich/poor; likely to win/lose

Model the world and have a utility measure for comparing future states. Choose the action with best expected utility. Calculate by averaging utility for all outcomes, weighted by outcome probability

Learning agents



The learning element makes improvements using feedback from the critic. The performance element selects external actions.

The problem generator suggests new actions - forcing the performance element to consider alternatives that might be an improvement

Summary

Agents interact with environments through actuators and sensors

The agent function describes what the agent does in all circumstances

The performance measure evaluates the environment sequence

A perfectly rational agent maximizes expected performance

Agent programs implement (some) agent functions

PEAS descriptions define task environments

Environments are categorized along several dimensions:
observable? deterministic? episodic? static? discrete? single-agent?

Several basic agent architectures exist:
reflex, reflex with state, goal-based, utility-based