Cognitive Systems

T6

2020 edition

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PSI 3560 – COGNITIVE SYSTEMS

class T6

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ARTIFICIAL INTELLIGENCE AND COGNITIVISM

Symbolic Approach, Symbol Systems, General Artificial Intelligence

Session T6

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Summary

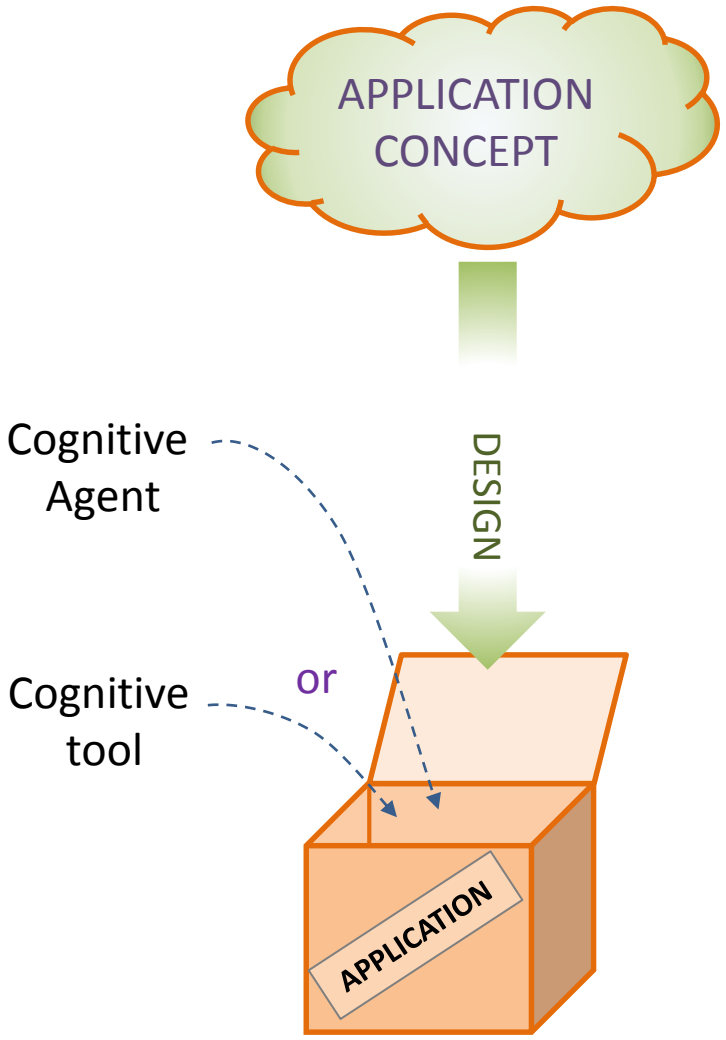
– Second session (9:20 – 11:00)

- Conceptual design of AI systems
- Symbol systems approach
- The AI agent

Design of a Cognitive System

- Conceptual analysis:
  - What the application does ?
    - » It is a cognitive system that does… ?
  - How does it do that ?
    - » Agent or tool ?
- After the formal statement of *what the application does*,

– Then comes the problem of **modelling the cognitive system**



Design of a Cognitive System

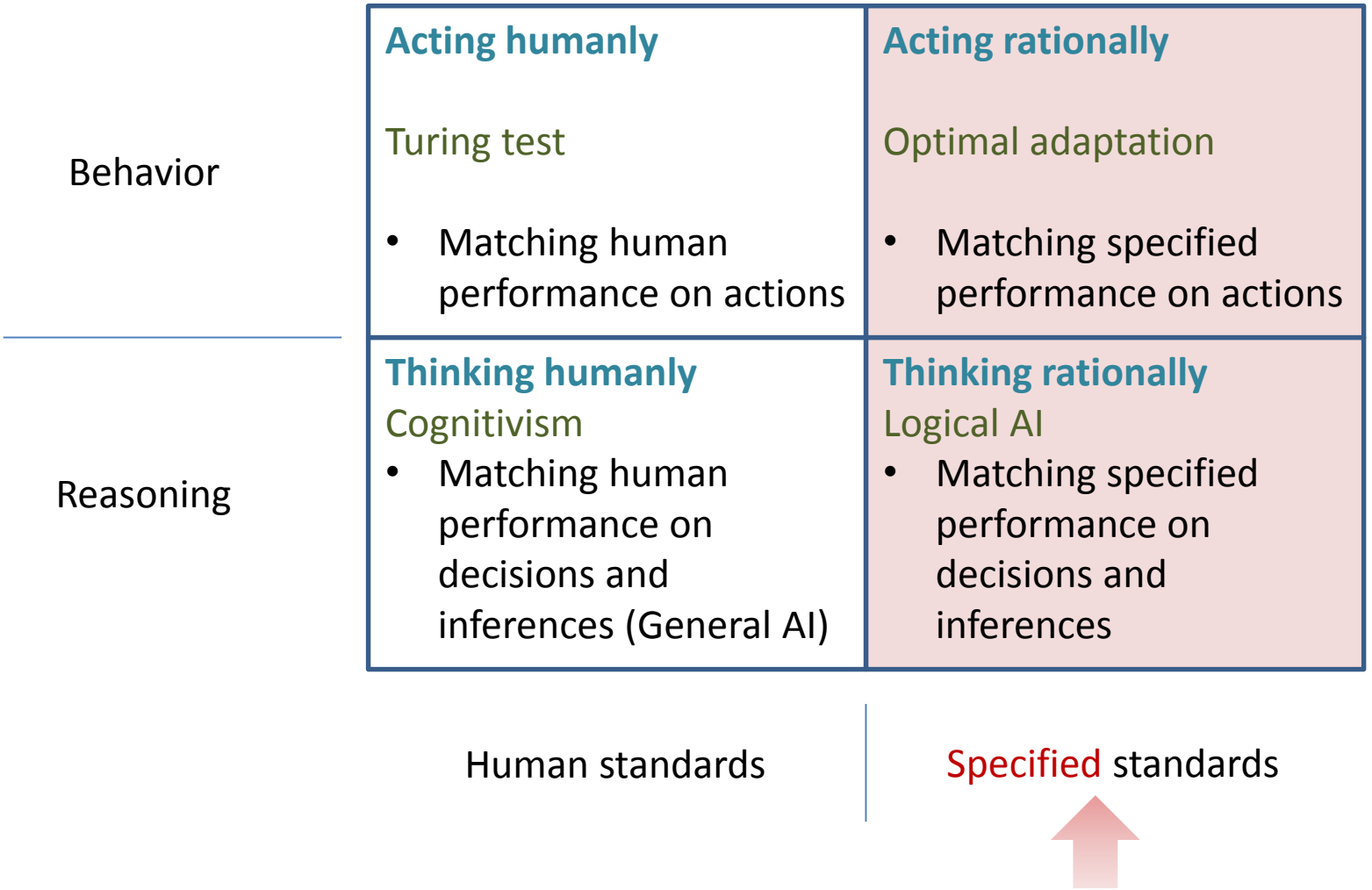
MODELLING THE COGNITIVE SYSTEM

- Marr's approach
  - Three levels of analysis
    - Computational model
      - » What kind of computations are required ?
      - » What is the nature of the computations ?
        - Logical, statistical , both ?
          - ARTIFICIAL INTELLIGENCE
          - MACHINE LEARNING
          - EVOLUTIVE SYSTEMS
    - Algorithmic specification
    - Physical implementation

Artificial Intelligence

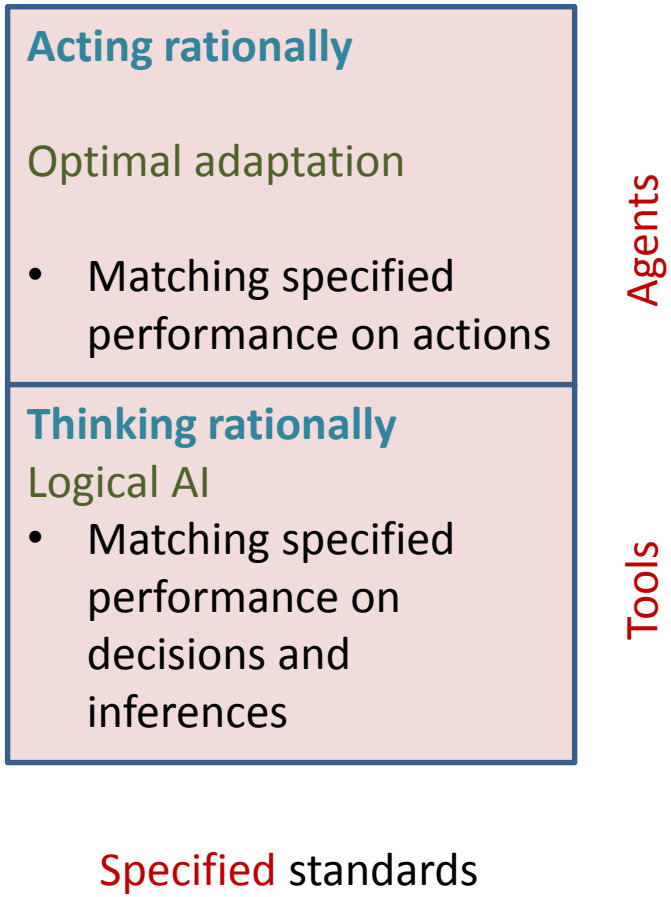
	Human standards	Specified standards
Behavior	**Acting humanly** Turing test • Matching human performance on actions	**Acting rationally** Optimal adaptation • Matching specified performance on actions
Reasoning	**Thinking humanly** Cognitivism • Matching human performance on decisions and inferences (General AI)	**Thinking rationally** Logical AI • Matching specified performance on decisions and inferences

Artificial Intelligence



Artificial Intelligence

- Agents
  - Examples
    - Autonomous robots
    - Manufacture cells
    - Intelligent environments
- Tools
  - Examples
    - Diagnostic systems
    - Expert systems
    - Coaching assistants
    - Decision-making assistants
    - Retailing assistants



Agent versus Tool

- Agent x Tool (for A.I.)
  - **Agent** → anything that perceive its environment through sensors and acts upon the environment through actuators. (Russell & Norvig, 1995-2010)
  - **Tool** → can be an agent (under AI view of Russell & Norvig)
    - Agent is an abstraction of interacting system
      - Inputs → perceptions
      - Outputs → actions

- Agent x Tool (Cognitive systems)
  - **Agent** → produces actions
  - **Tool** → helps an agent, which produces the actions

We will follow this view and adapt A.I.'s to ours

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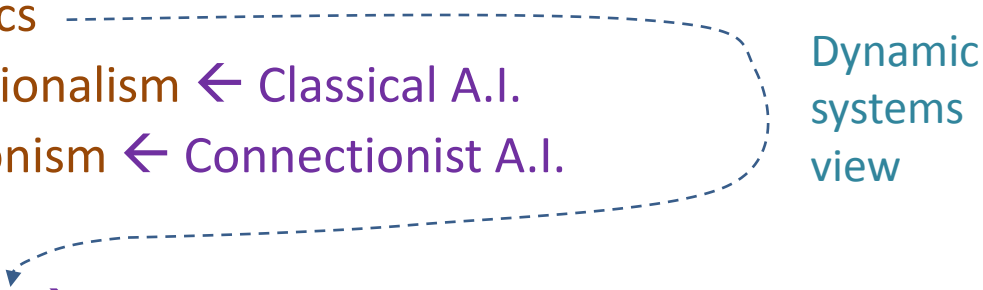
Artificial Intelligence vs. Cognitive Systems

- A.I. → two main phases
  - Classical
    - GOFAI – Good Old-fashioned A.I. (M. Boden)
    - Computationalist view → problem solving oriented
      - Modular (functional) architecture
      - Symbol system manipulation
      - Based on logical-deductive formalism
  - Connectionist A.I.
    - Machine learning
    - Connectionist view → data associations oriented
      - Network (topological) architecture
      - Learning of associations
      - Based on statistical formalism

Artificial Intelligence vs. Cognitive Systems

- Cognitive Systems
  - Cognitive science views
    - Internalism
      - Cybernetics
      - Computationalism ← Classical A.I.
      - Connectionism ← Connectionist A.I.
    - Externalism
      - Enactivism → Cognitive robotics
      - Distributed cognition → Cognitive environments
  - No connection with data analytics
      - It is just A.I.
      - It could be cognitive tool



Artificial Intelligence vs. Cognitive Systems

- Problem solving
  - Computer science → study of problems
    - Computer : activity vs. machine
    - Problem components
      - States
        - » Initial state
        - » Final (desired) state
      - Process
        - » Process of solution
      - Conditioning
        - » Restrictions
        - » Requirements
      - Statement

Artificial Intelligence vs. Cognitive Systems

- Agent approach vs. Problem solving
  - Agent behavior
    - Sequence of actions
      - Consequences of the actions
        - » Change the state of the environment
  - Agent behavior as problem solving
      - Natural behavior
        - » Nomological aspect
          - Trial-and-error approach
      - Prescribed behavior
        - » Normative aspect
          - Design approach
            - Follow prescriptions

Artificial Intelligence vs. Cognitive Systems

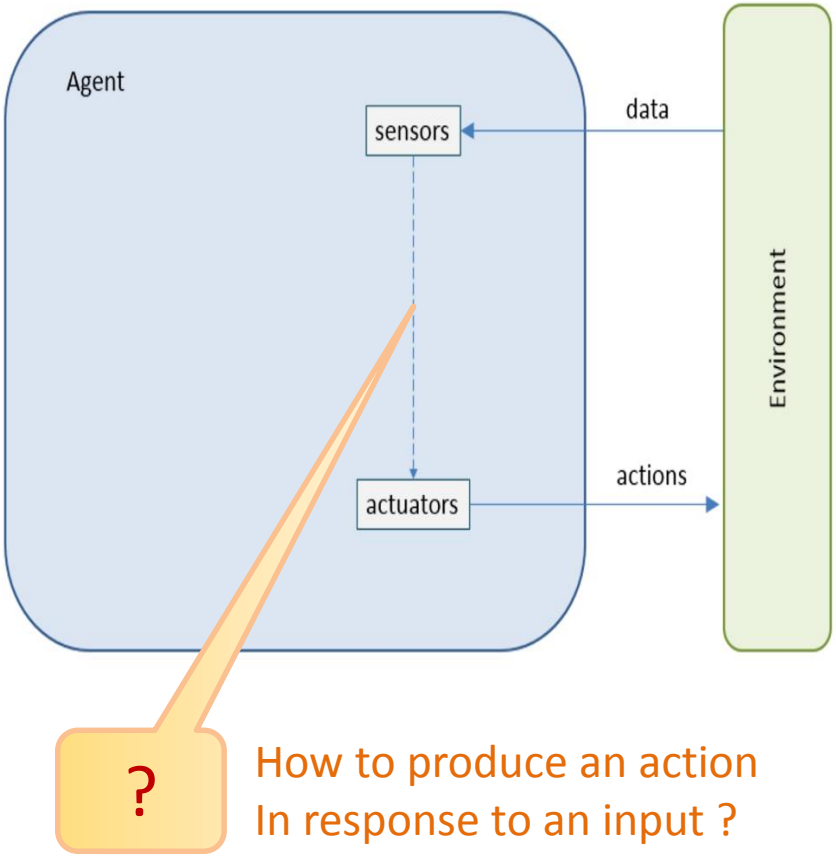
- Agent behavior as problem solving
  - Design approach
    - Goal
    - Task
      - Process → state transition
      - Task → state transformation
        - » Elementary changes → unitary operations
      - Task presupposed functionality
    - Solution
    - Design methodology
      - Functional capacity
      - Modularity
      - Methodological reduction
        - » Top-down decomposition → analytical reduction
        - » Bottom-up composition → synthetical reduction
      - Rational condition

Artificial Intelligence vs. Cognitive Systems

- Agent behavior as problem solving
  - Design approach
    - Design methodology
      - Rational condition
        - » Rationality
          - Rational → ratio, proportion, fitness
          - Reasoning → reason, satisfaction, correctness
  - Reasoning agent → logical inferences
    - Deduction → propositional calculus
      - Syntactic structure
      - Semantic mapping
      - Conceptual abstraction
        - » Symbolic representation
        - » Symbol system
        - » Symbol grounding
        - » Symbol manipulation

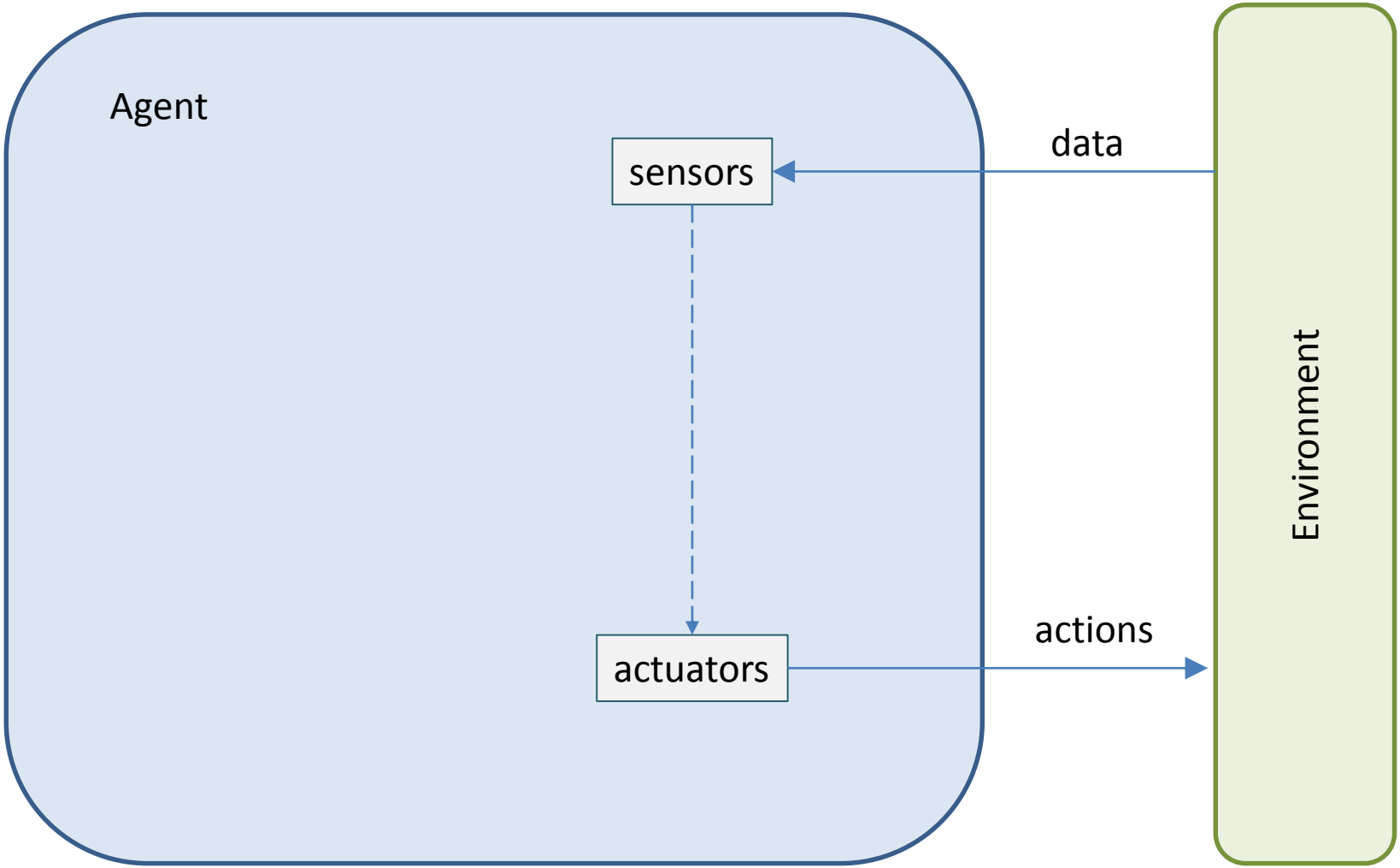
Artificial Intelligence vs. Cognitive Systems

- Reasoning agents
  - Reactive agents
    - Reflex agent
    - Conditional reflex agent
  - Model-based agents
    - Predictive agent
    - Goal-following agent
      - Planning agent
    - Optimizing agent
      - Utility-based agent
  - Learning agent



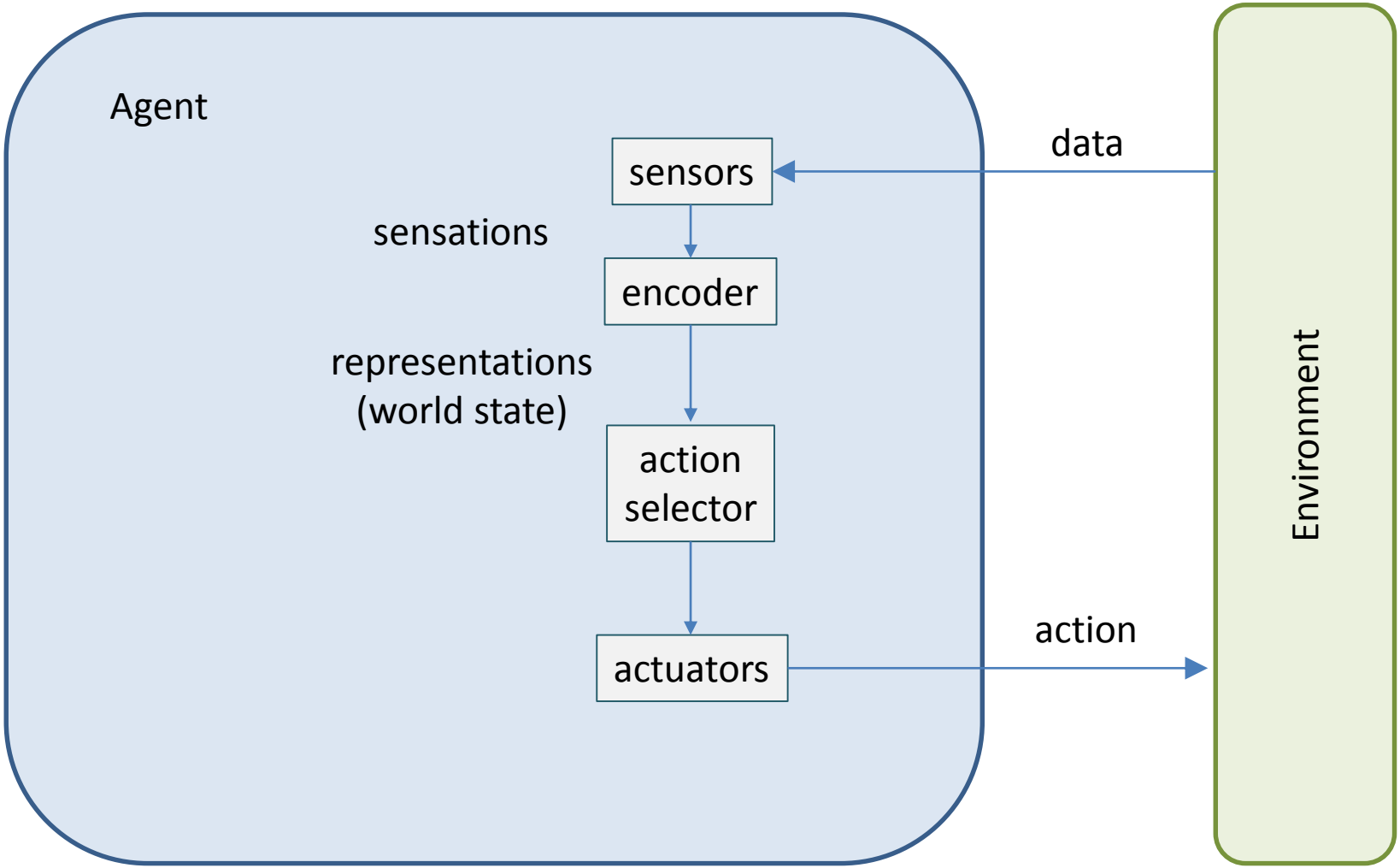
- Cognitive agents

The AI agent

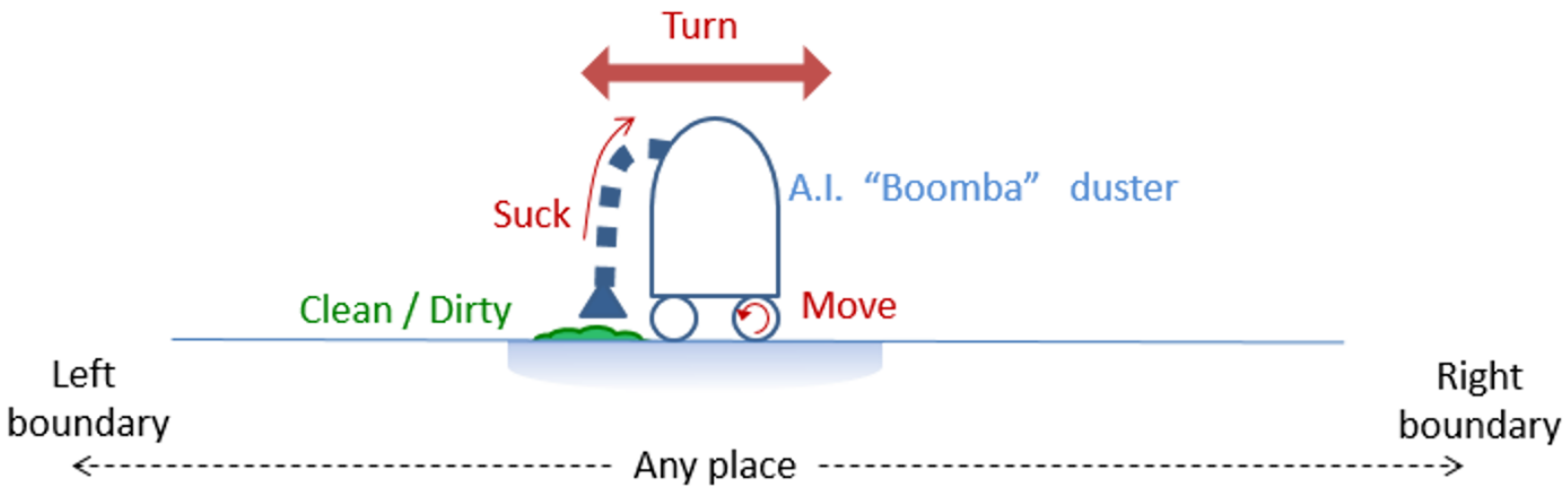


The AI agent

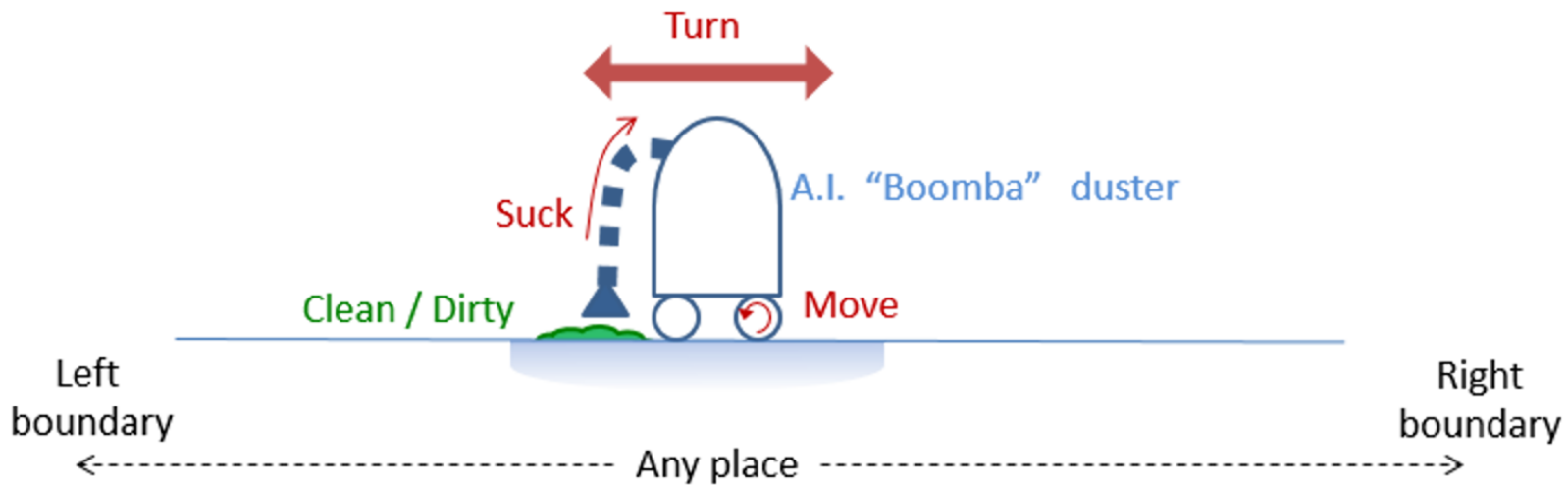
Reflex agent

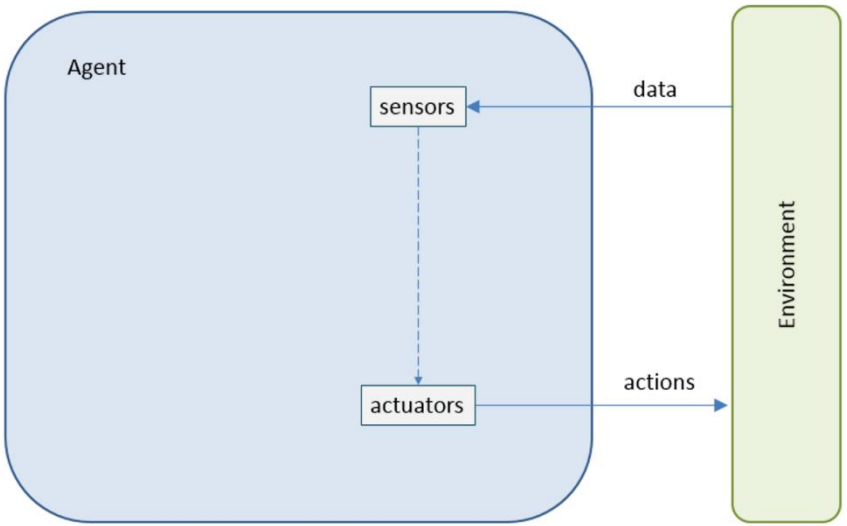


Example


Turn
Suck
A.I. "Boomba" duster
Clean / Dirty
Move
Left boundary
Right boundary
Any place

Example

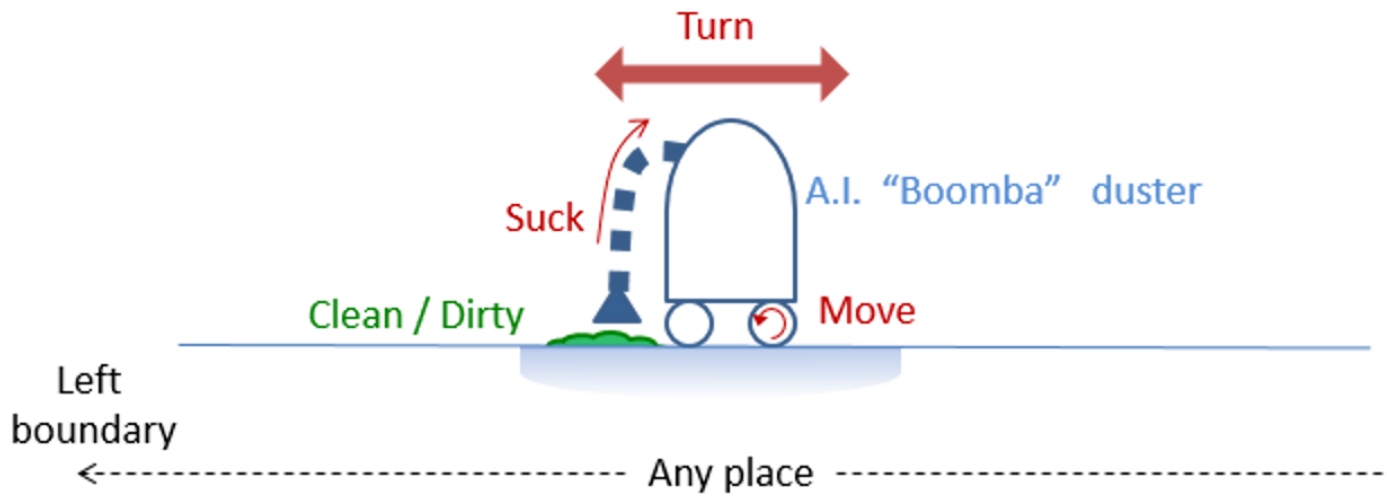


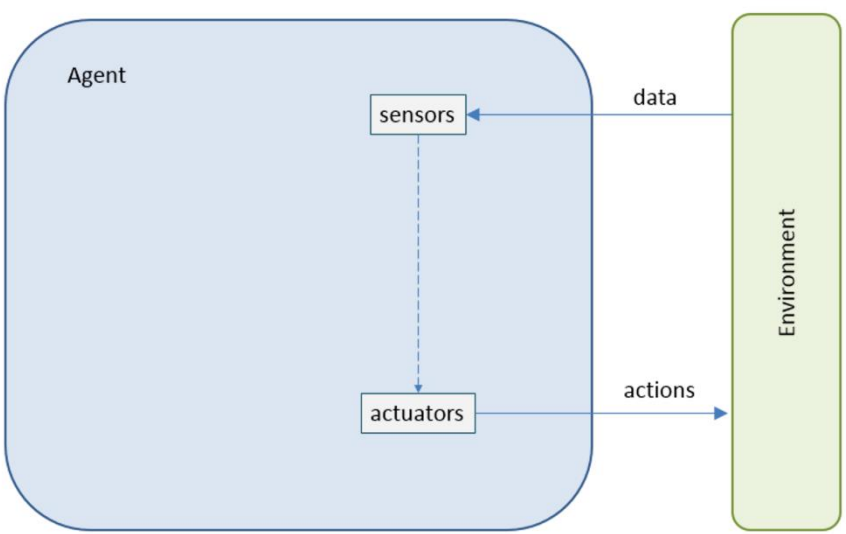


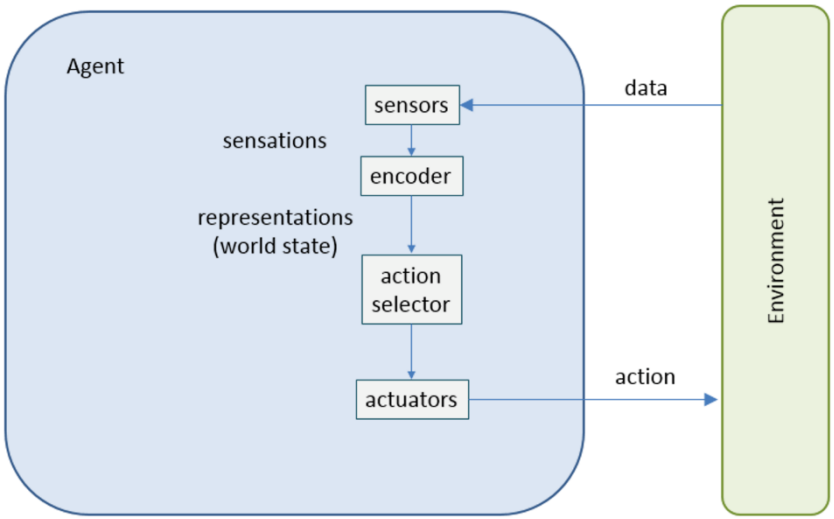
Sensors → give information about the world's and agent's state variables

Actuators → perform actions changing the relations between the agent's state and the word's state

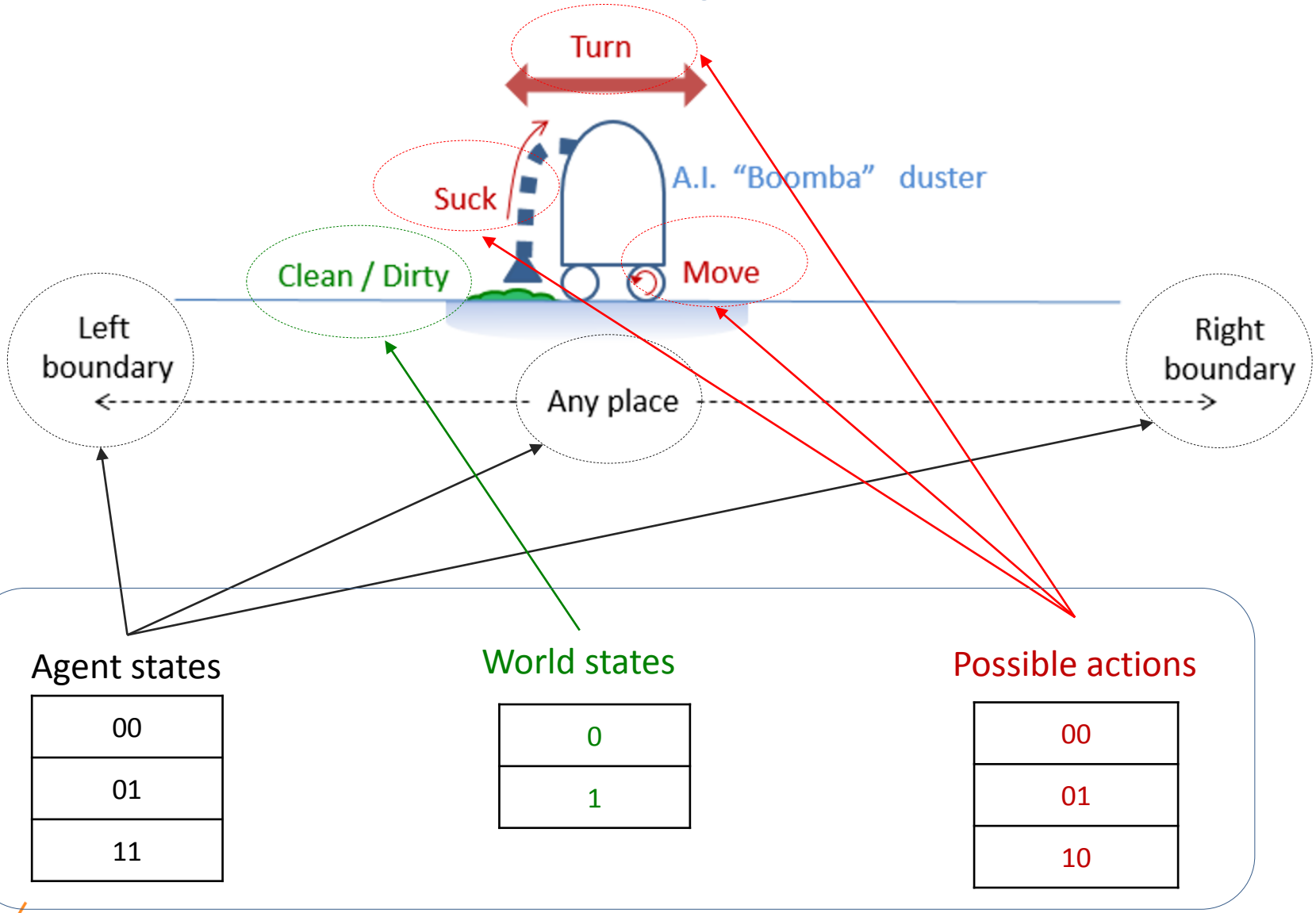
Example


Turn
Suck
A.I. "Boomba" duster
Clean / Dirty
Move
Left boundary
Right boundary
Any place

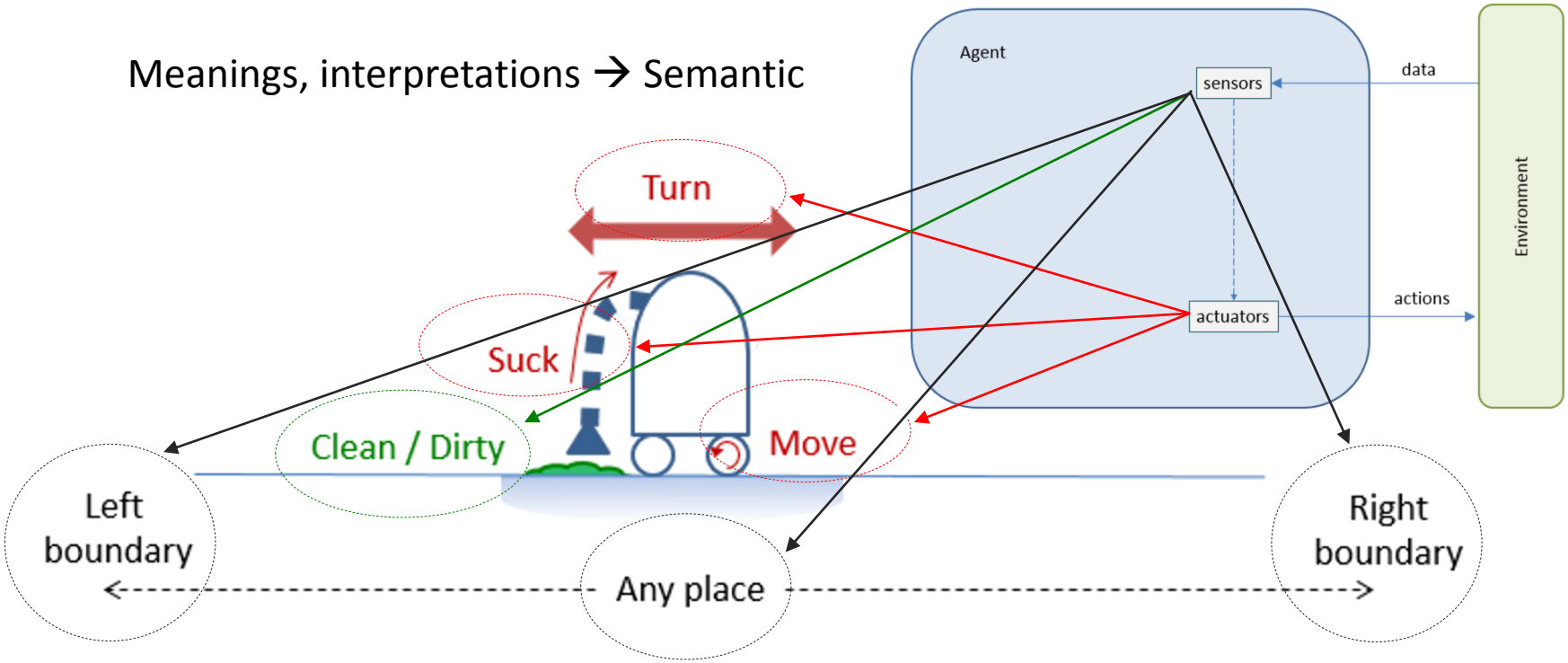

Agent
sensors
data
actuators
actions
Environment


Agent
sensors
data
sensations
encoder
representations
(world state)
action
selector
actuators
action
Environment

Example


Turn
Suck
A.I. "Boomba" duster
Clean / Dirty
Move
Left boundary
Any place
Right boundary
Agent states
00
01
11
World states
0
1
Possible actions
00
01
10

Meanings, interpretations → Semantic



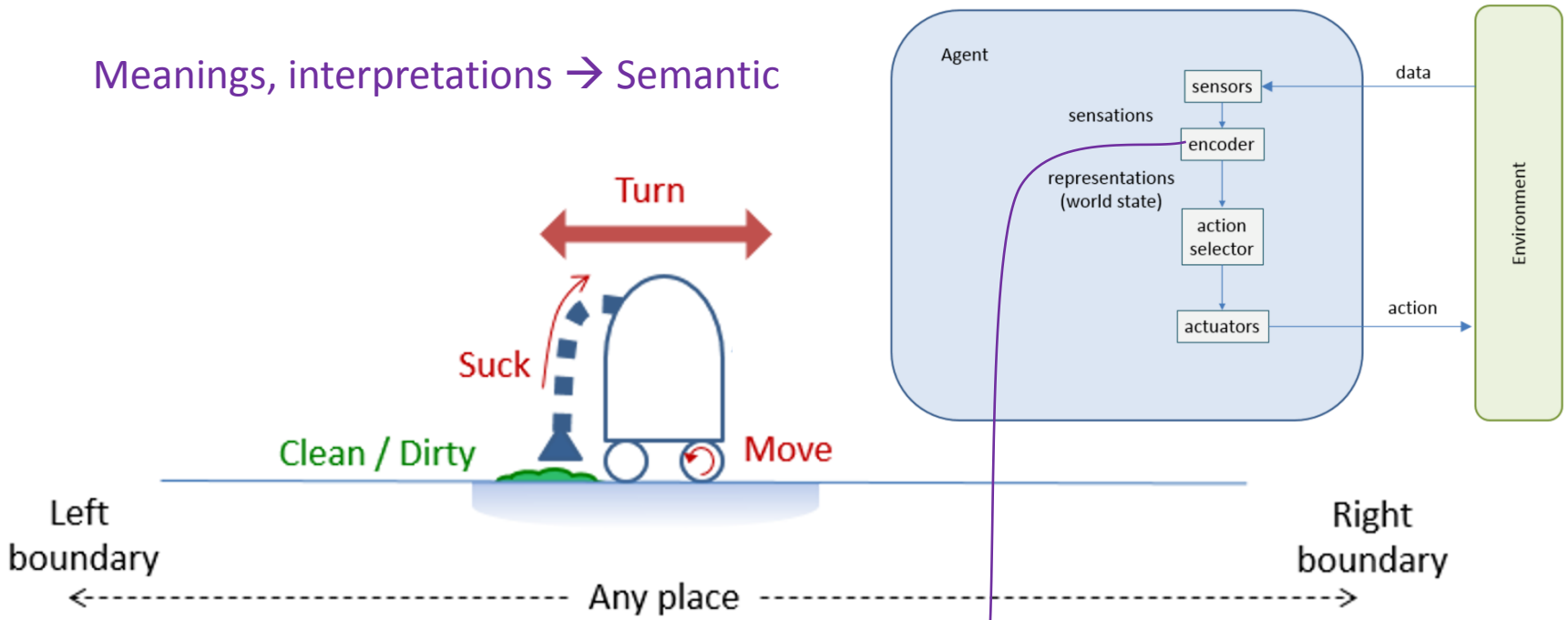
Codes. representations → Symbol system

Agent states
00
01
11

World states
0
1

Possible actions
00
01
10

Meanings, interpretations → Semantic



Codes. representations → Symbol system

Internal meanings

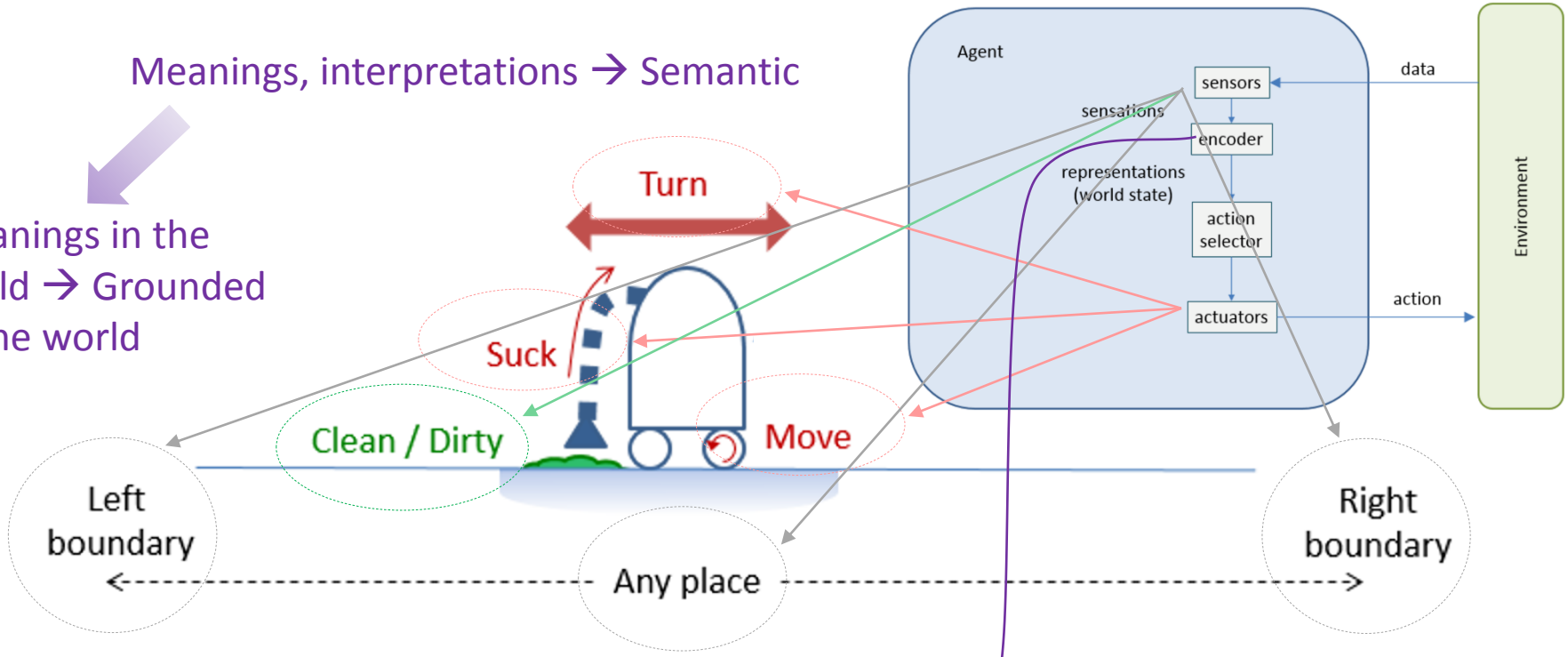
Agent states
00
01
11

World states
0
1

Possible actions
00
01
10

Meanings, interpretations → Semantic

Meanings in the world → Grounded In the world



Codes. representations → Symbol system

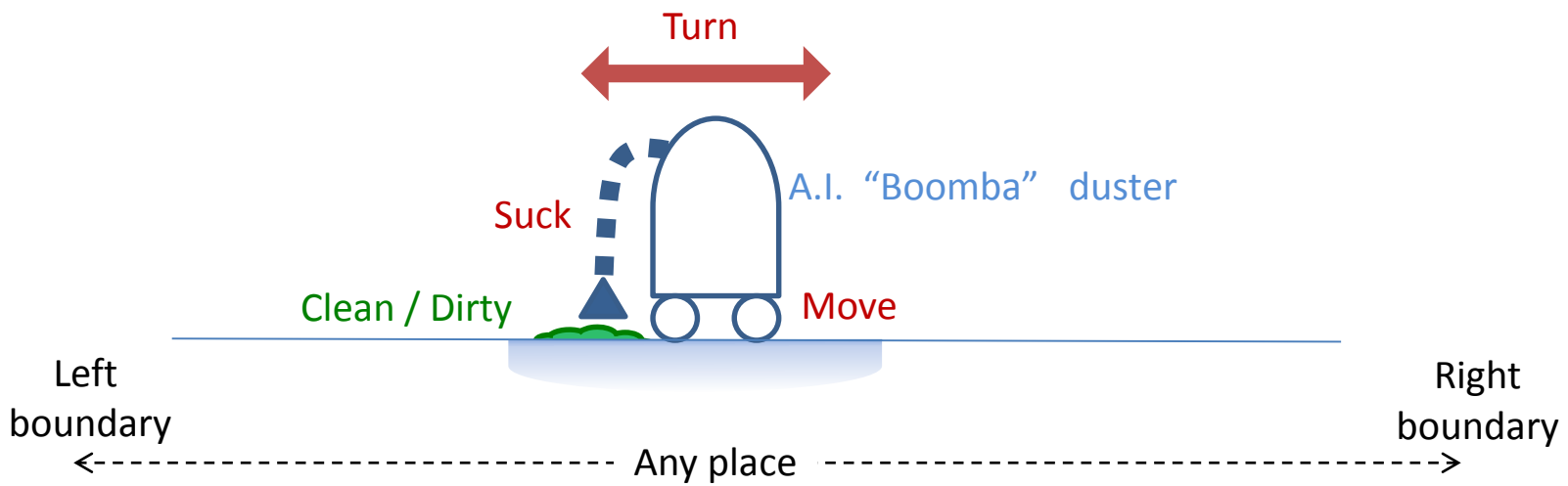
Internal meanings

Agent states
00
01
11

World states
0
1

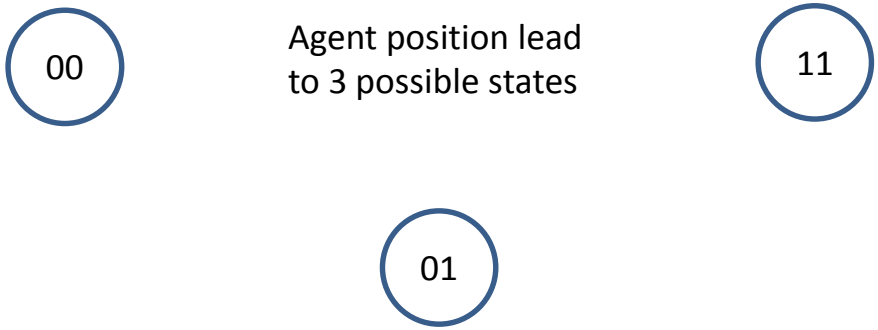
Possible actions
00
01
10

Example



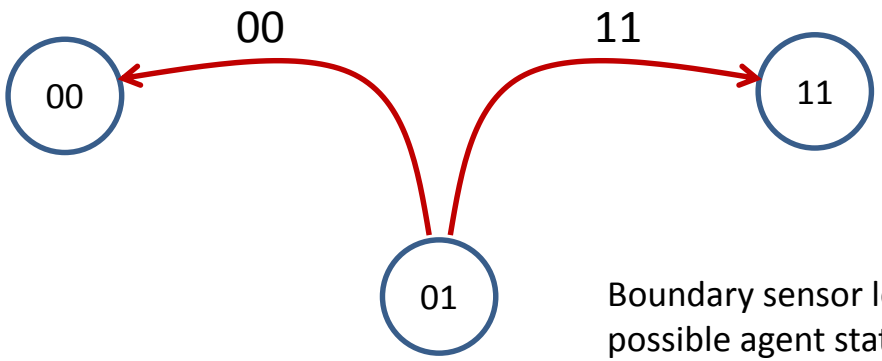
Agent Position	World Status	Code	Action	Action Code
Left boundary	Clean	000	Turn	00
Left boundary	Dirty	001	Suck	01
Any place	Clean	010	Move	10
Any place	Dirty	011	Suck	01
Right boundary	Clean	110	Turn	00
Right boundary	Dirty	111	Suck	01

Example



Agent Position	World Status	Code	Action	Action Code
Left boundary	Clean	000	Turn	00
Left boundary	Dirty	001	Suck	01
Any place	Clean	010	Move	10
Any place	Dirty	011	Suck	01
Right boundary	Clean	110	Turn	00
Right boundary	Dirty	111	Suck	01

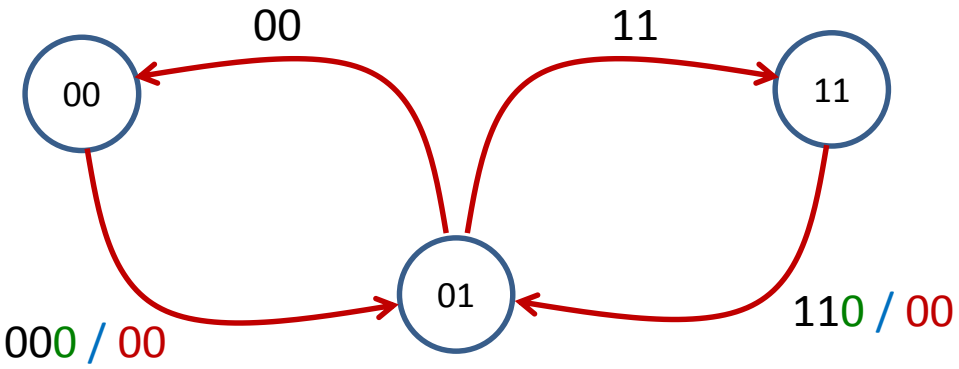
Example



Boundary sensor lead to 2 possible agent state transitions

Agent Position	World Status	Code	Action	Action Code
Left boundary	Clean	000	Turn	00
Left boundary	Dirty	001	Suck	01
Any place	Clean	010	Move	10
Any place	Dirty	011	Suck	01
Right boundary	Clean	110	Turn	00
Right boundary	Dirty	111	Suck	01

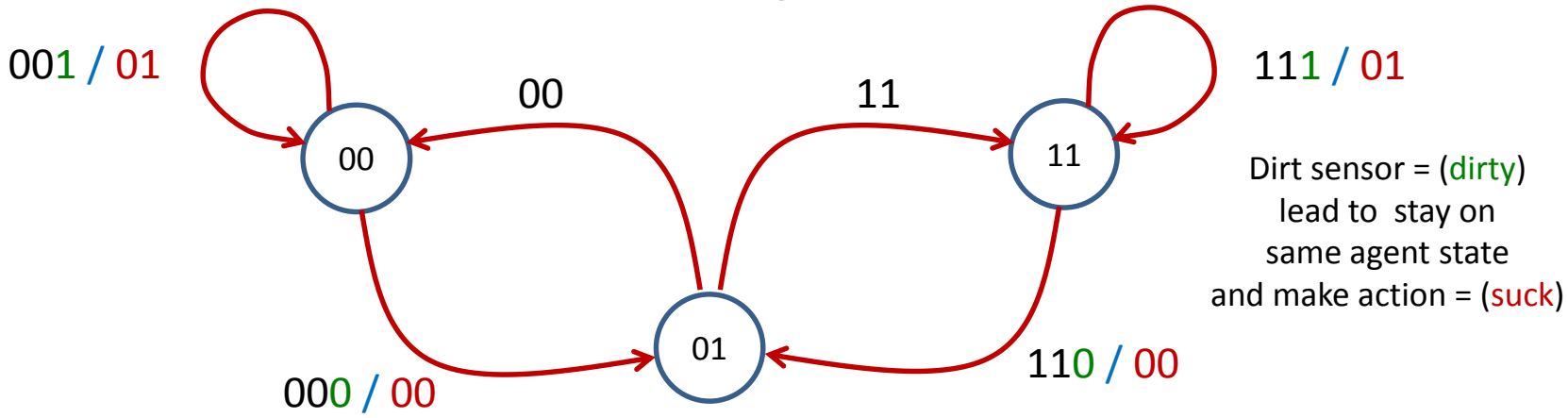
Example



Dirt sensor = (clean)
lead to 2 more
agent state transitions
by making action = (turn)

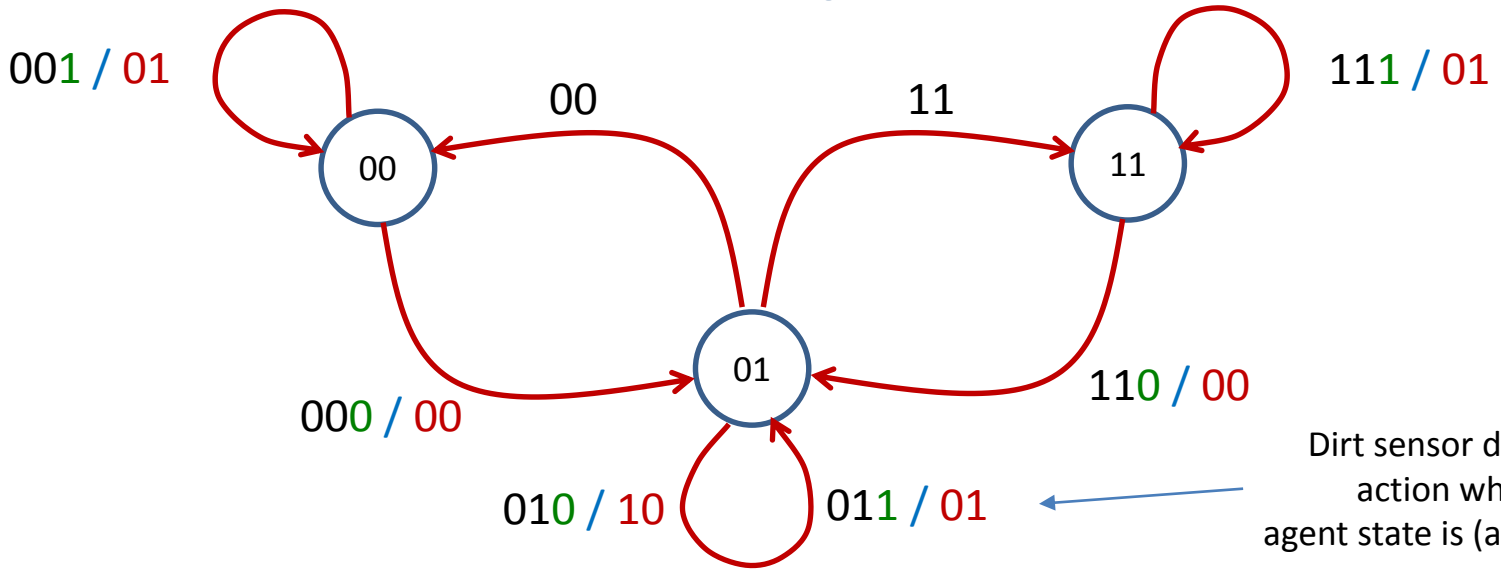
Agent Position	World Status	Code	Action	Action Code
Left boundary	Clean	000	Turn	00
Left boundary	Dirty	001	Suck	01
Any place	Clean	010	Move	10
Any place	Dirty	011	Suck	01
Right boundary	Clean	110	Turn	00
Right boundary	Dirty	111	Suck	01

Example



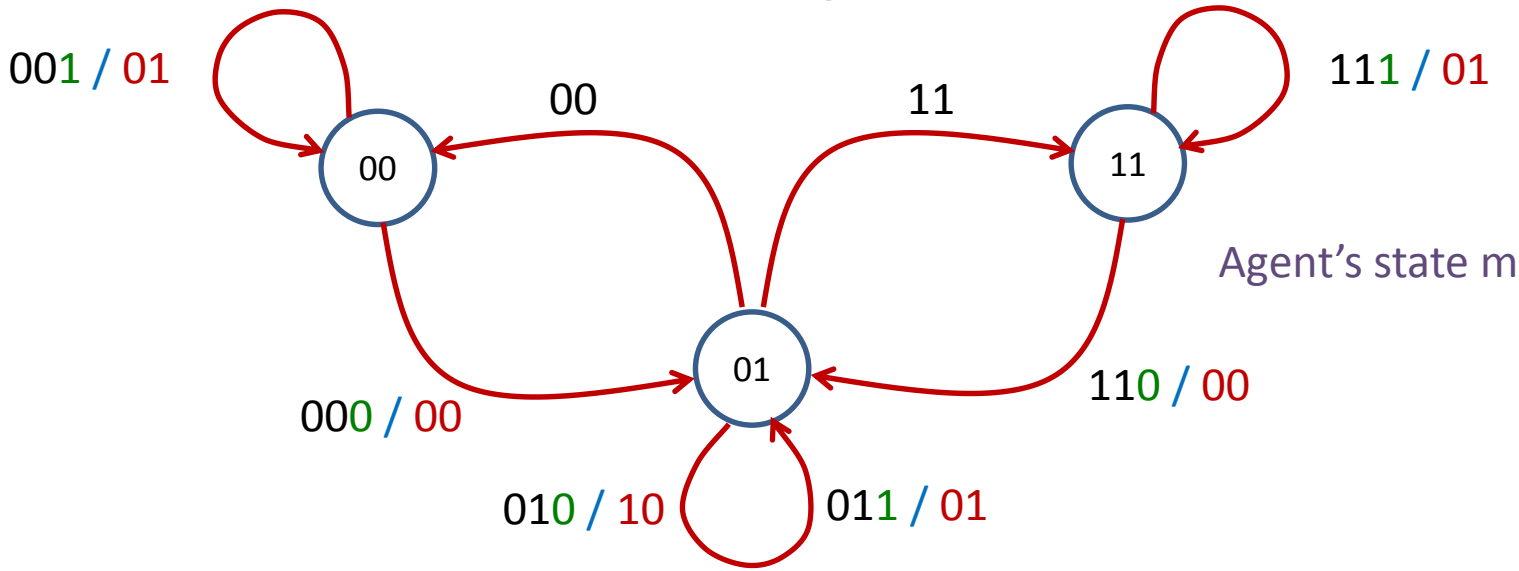
Agent Position	World Status	Code	Action	Action Code
Left boundary	Clean	000	Turn	00
Left boundary	Dirty	001	Suck	01
Any place	Clean	010	Move	10
Any place	Dirty	011	Suck	01
Right boundary	Clean	110	Turn	00
Right boundary	Dirty	111	Suck	01

Example



Agent Position	World Status	Code	Action	Action Code
Left boundary	Clean	000	Turn	00
Left boundary	Dirty	001	Suck	01
Any place	Clean	010	Move	10
Any place	Dirty	011	Suck	01
Right boundary	Clean	110	Turn	00
Right boundary	Dirty	111	Suck	01

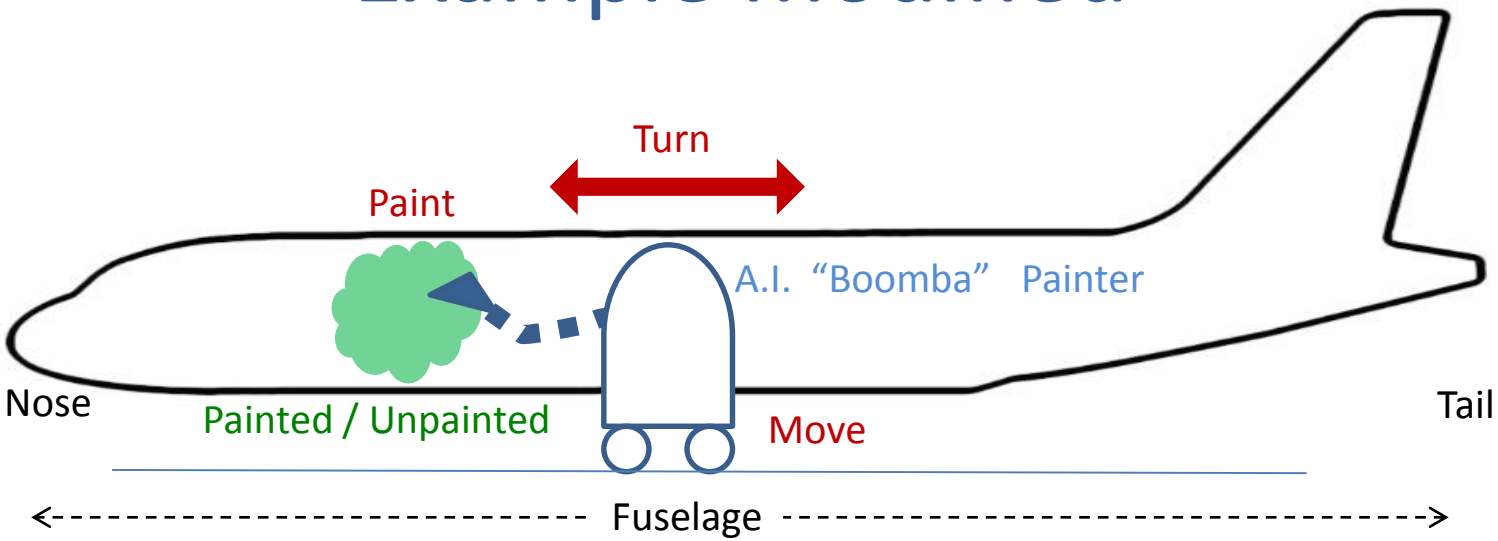
Example



Agent's state machine

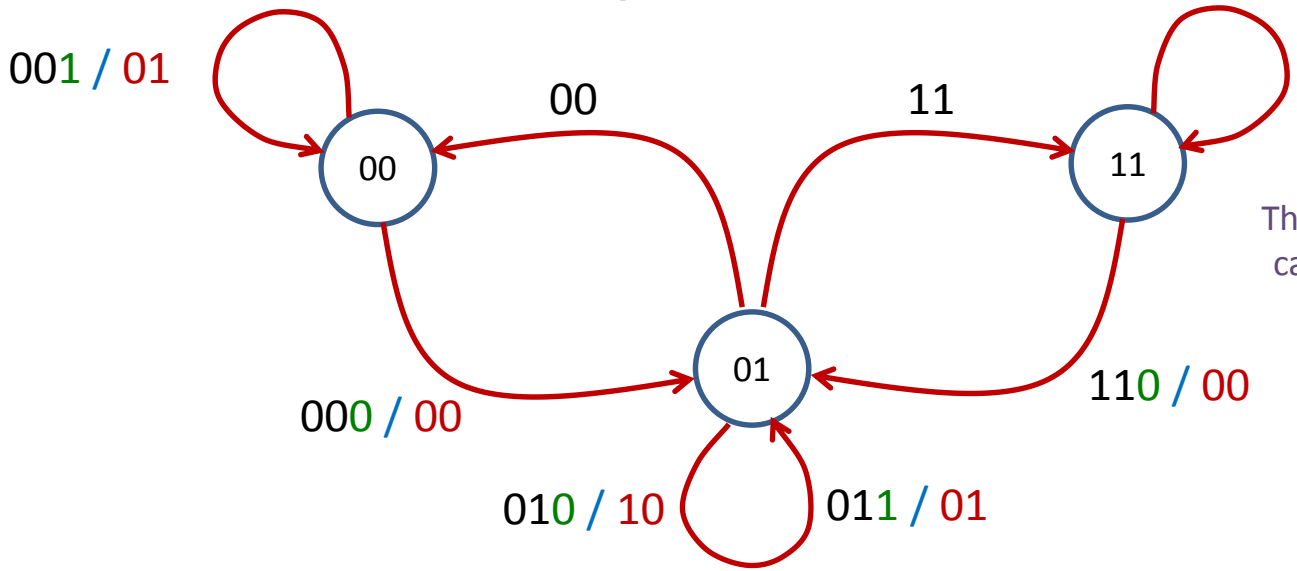
Agent Position	World Status	Code	Action	Action Code
Left boundary	Clean	000	Turn	00
Left boundary	Dirty	001	Suck	01
Any place	Clean	010	Move	10
Any place	Dirty	011	Suck	01
Right boundary	Clean	110	Turn	00
Right boundary	Dirty	111	Suck	01

Example modified



Agent Position	World Status	Code	Action	Action Code
Nose	Painted	000	Turn	00
Nose	Unpainted	001	Paint	01
Fuselage	Painted	010	Move	10
Fuselage	Unpainted	011	Paint	01
Tail	Painted	110	Turn	00
Tail	Unpainted	111	Paint	01

Example modified

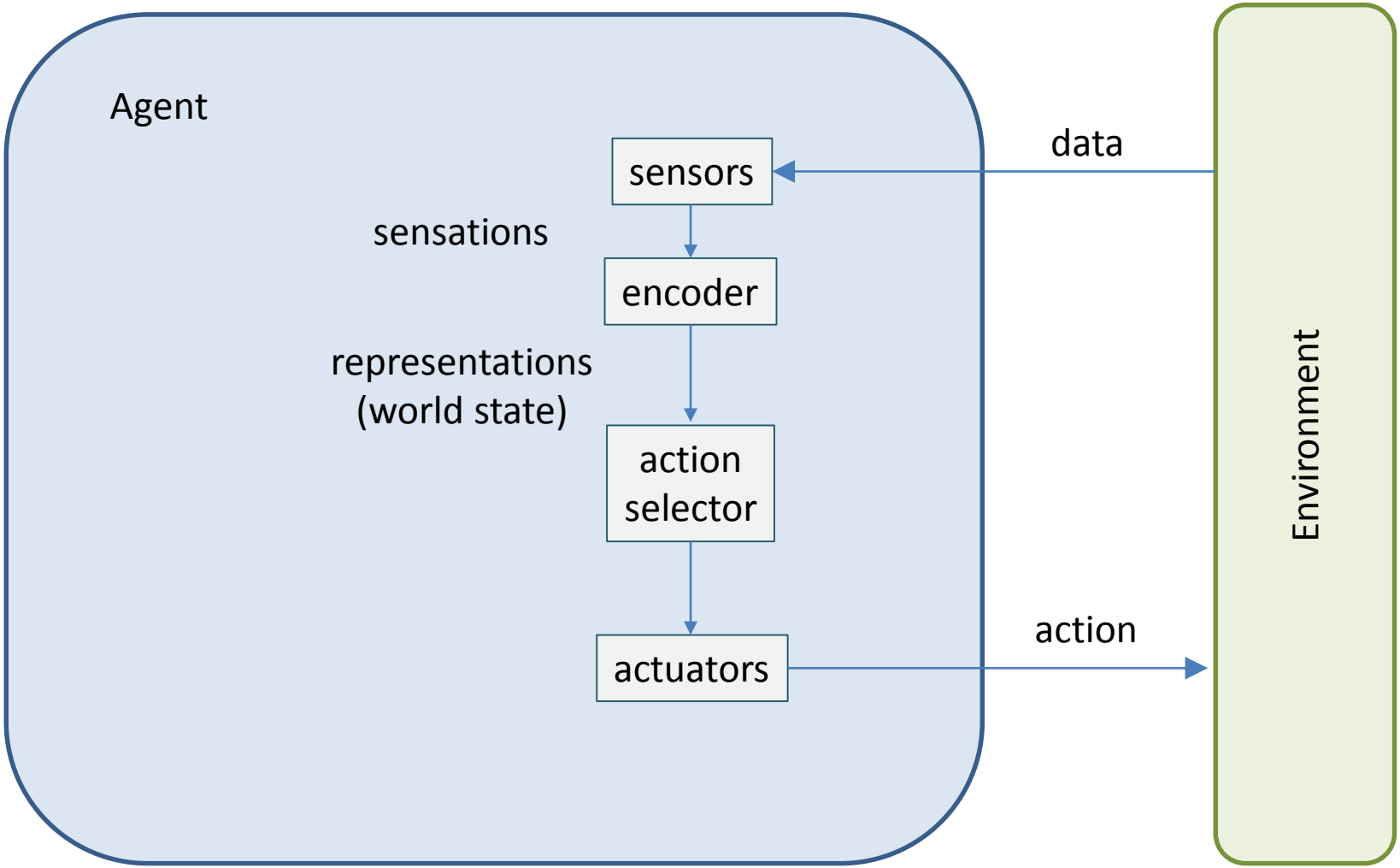


The same state machine can be used regardless of meanings

Agent Position	World Status	Code	Action	Action Code
Nose	Painted	000	Turn	00
Nose	Unpainted	001	Paint	01
Fuselage	Painted	010	Move	10
Fuselage	Unpainted	011	Paint	01
Tail	Painted	110	Turn	00
Tail	Unpainted	111	Paint	01

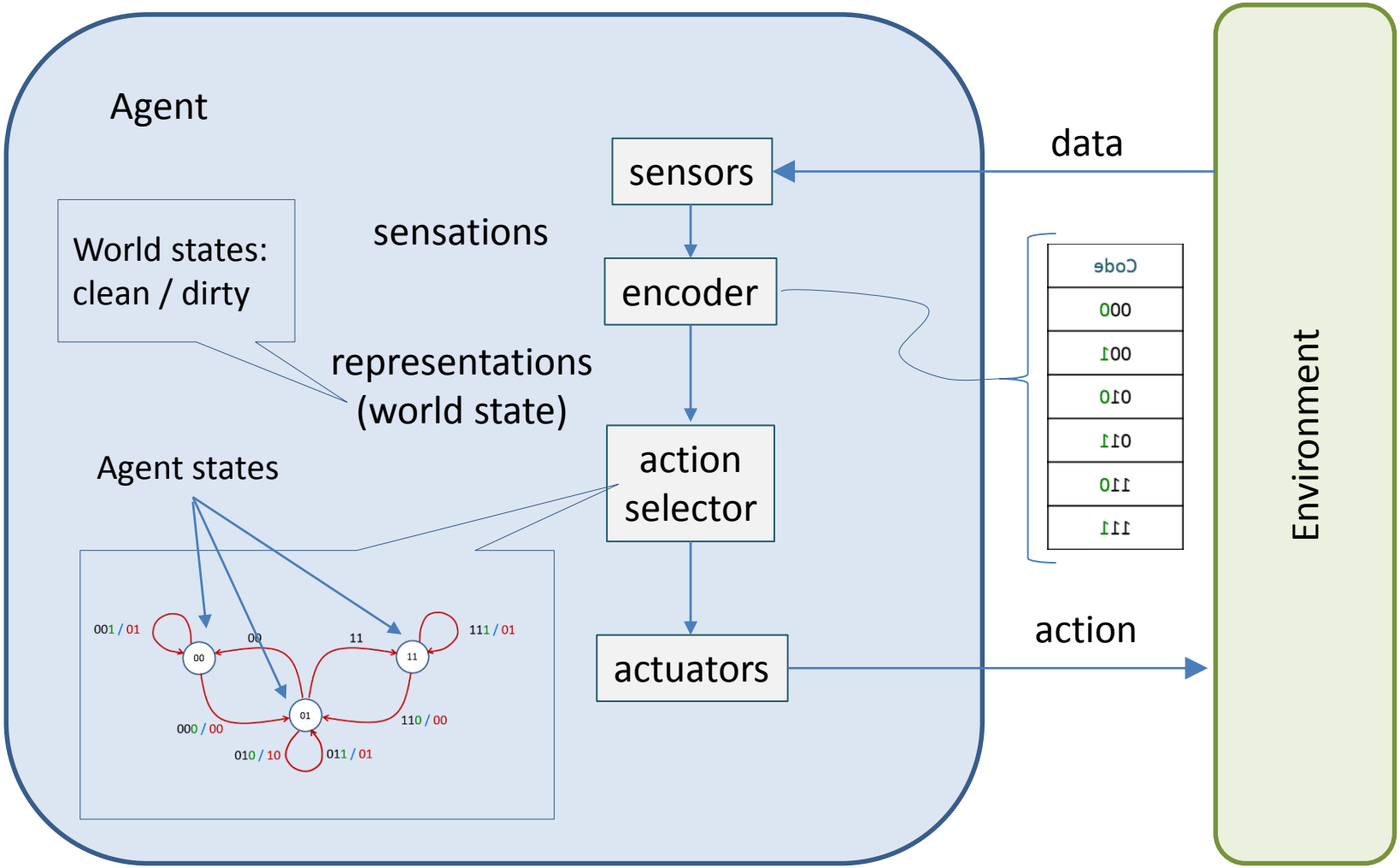
The AI agent

Reflex agent



The AI agent

Reflex agent



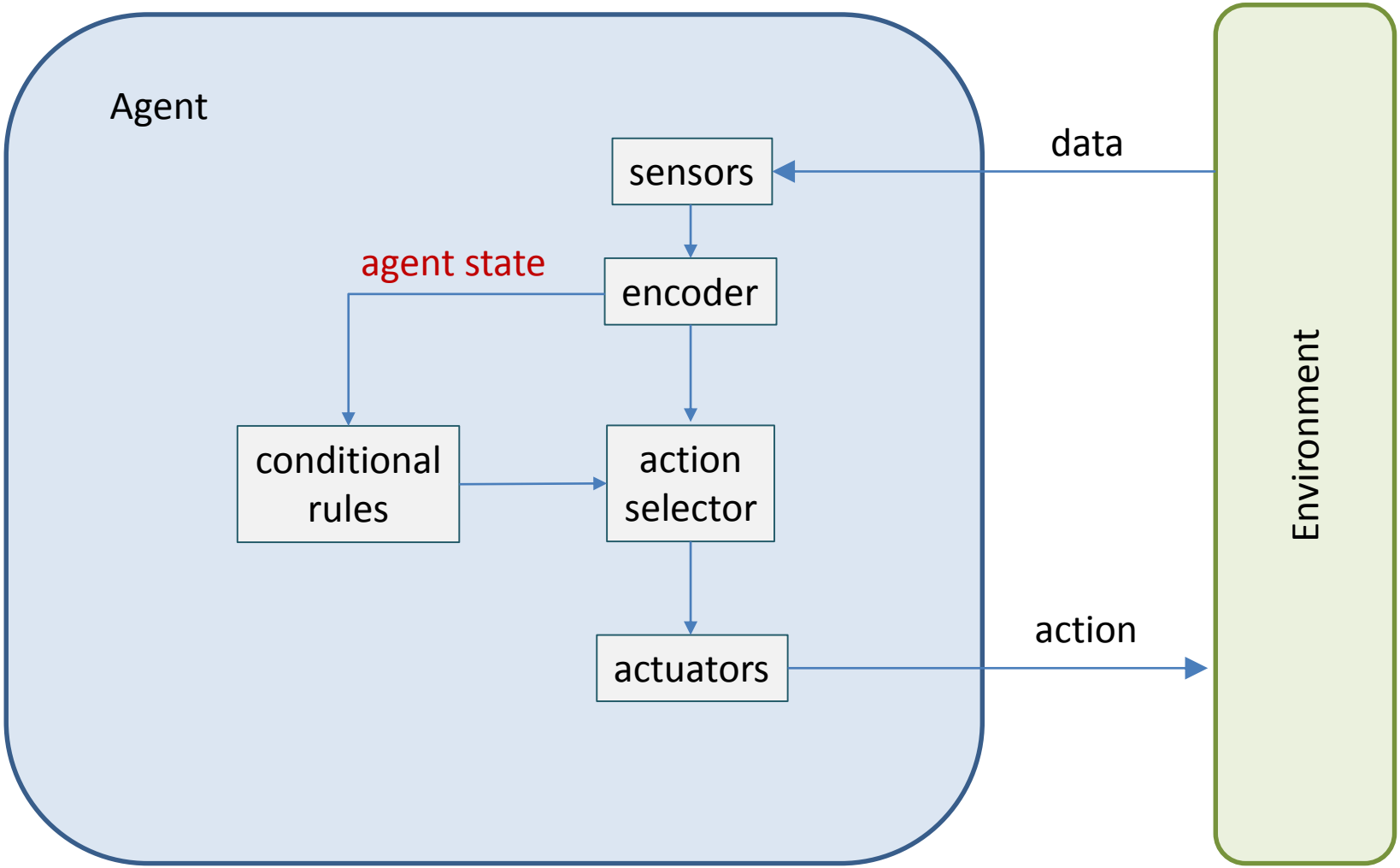
Artificial Intelligence vs. Cognitive Systems

- Reflex agent
  - Actions are selected as reactions to world states
    - Input → world state (from sensors)
    - Output → agent actions (via effectors)
    - Action selection → function mapping
      - LUT → look-up table
      - Functional expression
        - » First-order propositional calculus
          - Functions of the logical variables

    - Drawback: how to stop the examples' agents ?
- Conditional reflex agent

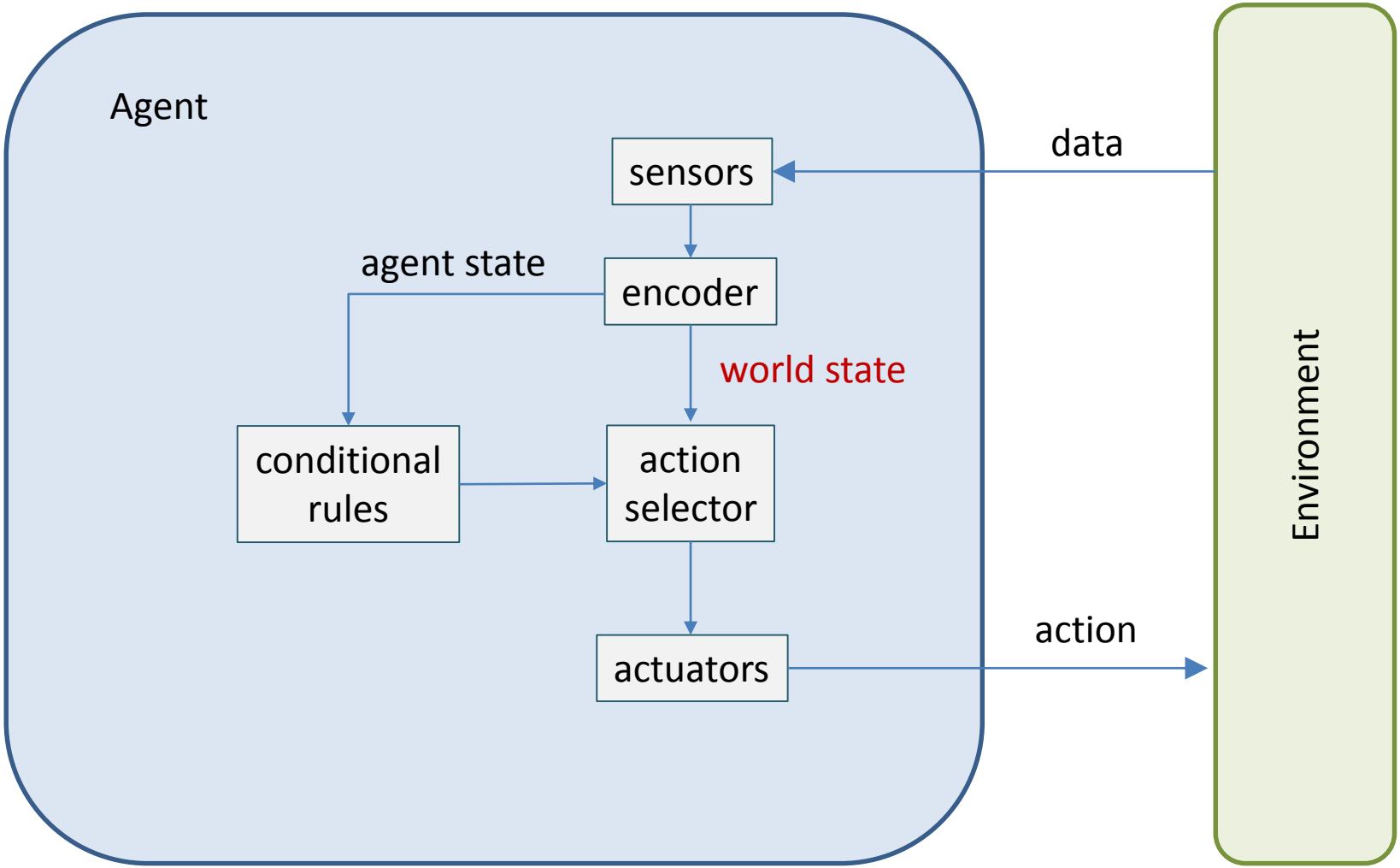
The AI agent

Conditional reflex agent



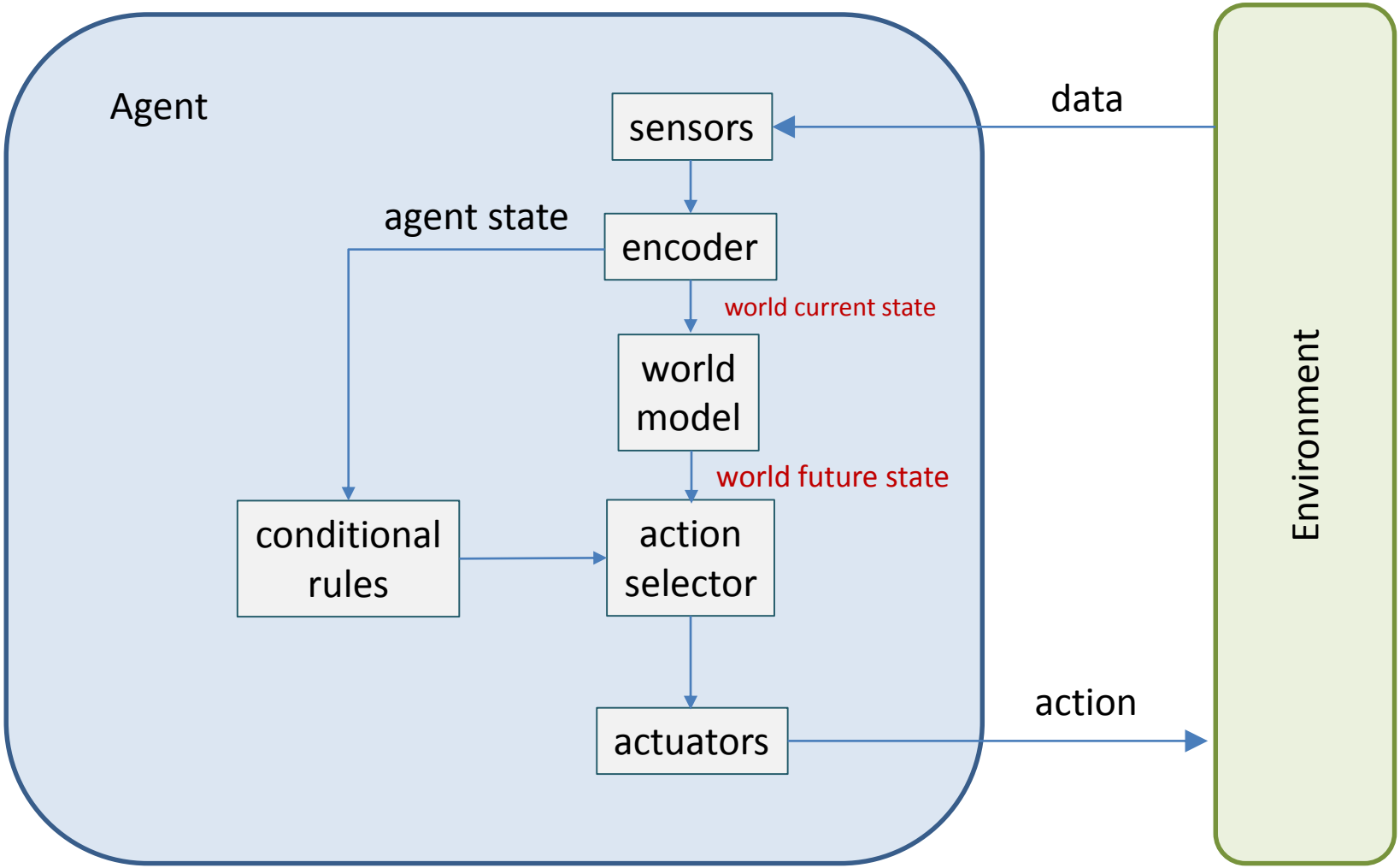
The AI agent

Conditional reflex agent

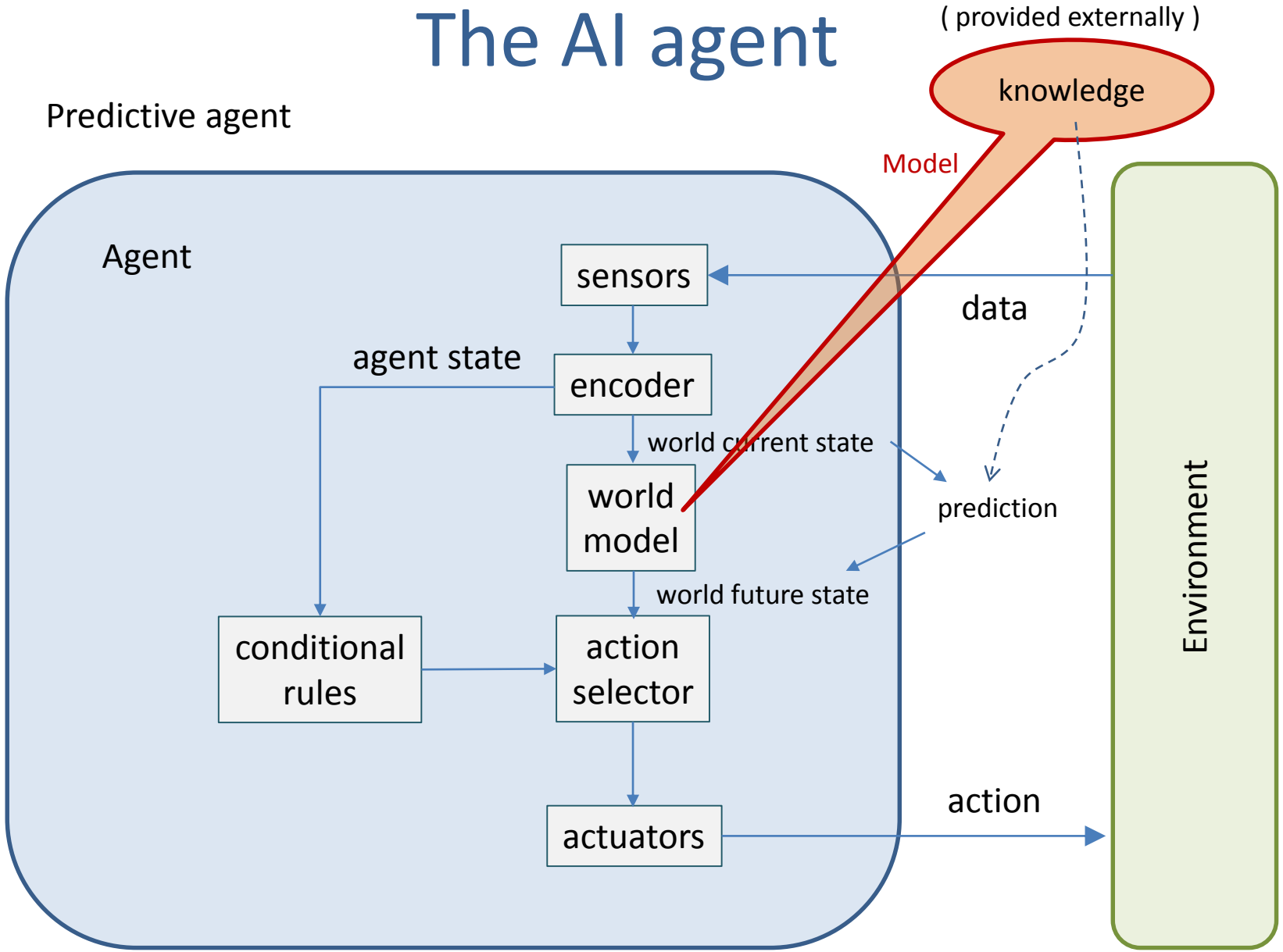


The AI agent

Predictive agent



The AI agent



Model-based prediction → predictive model

Artificial Intelligence vs. Cognitive Systems

- Reasoning agent → logical inferences
  - Deduction → propositional calculus
    - Propositional implications lead to syntactic consequences
    - Semantic mapping → models
  - Symbol manipulation
    - Syntactic manipulation → to produce inferential sentences
    - Semantics → mapped do inferential sentences
      - Interpretations have meaning in the world
        - » Symbol grounding
    - Knowledge can't be deduced
      - It must be provided externally
        - » Notice that knowledge is not built with A.I.
          - It is provided to the system

Deductive versus Inductive

- The cognitive quest
  - Cognition → Knowledge
    - Build it, use it…
    - Classical A.I. ("GOFAI")
      - Deductive inferences only
      - Knowledge is provided **externally to the system** …
      - … at the system project phase → it is formally introduced
        - » No knowledge is actually produced by the system
        - » It is only transformed:
          - Everything is reduced to a symbol system
            - Inferences come from symbol manipulations
      - No knowledge building, no cognition

Deductive versus Inductive

- The cognitive quest
  - Cognition → Knowledge
    - Build it, use it…
    - Change deductive inference to inductive inference
      - Probabilistic inference
      - Machine Learning
        - » Is here a hope for building knowledge ?
        - » Knowledge can be learned from the data …
        - » … through an inductive process
          - The inductive process detects patterns in the data
            - These patterns bring the invariants
              - … that make the knowledge…

This is all for today.