# Foundations of Artificial Intelligence

## A4. Introduction: Rational Agents

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February 28, 2024 — A4. Introduction: Rational Agents

# Introduction: Overview

Chapter overview: introduction

- A1. Organizational Matters
- A2. What is Artificial Intelligence?
- A3. AI Past and Present
- A4. Rational Agents
- A5. Environments and Problem Solving Methods

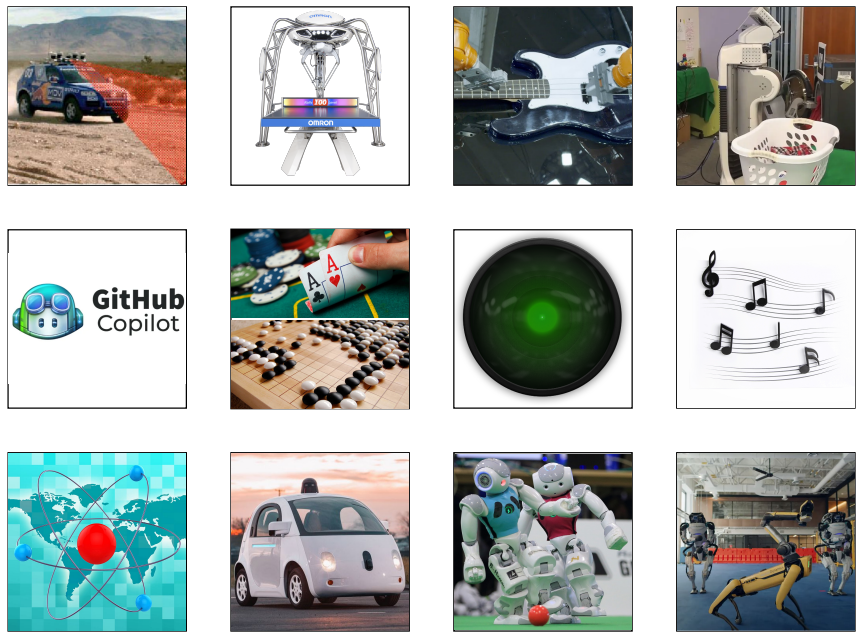
# A4.1 Systematic AI Framework

# Systematic AI Framework

so far we have seen that:

- AI systems act rationally


- AI systems applied to wide variety of challenges




now: describe a systematic framework that

- captures this diversity of challenges
- includes an entity that is acting in the environment
- determines if the agent acts rationally in the environment

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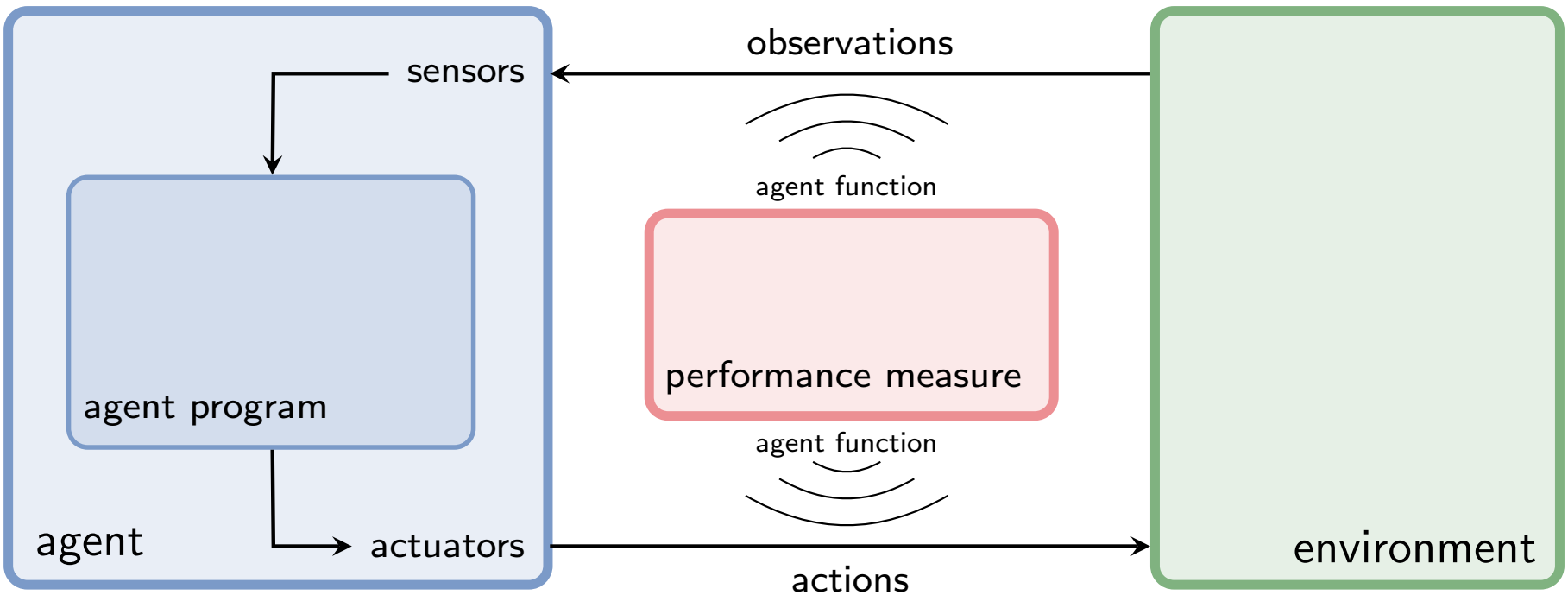


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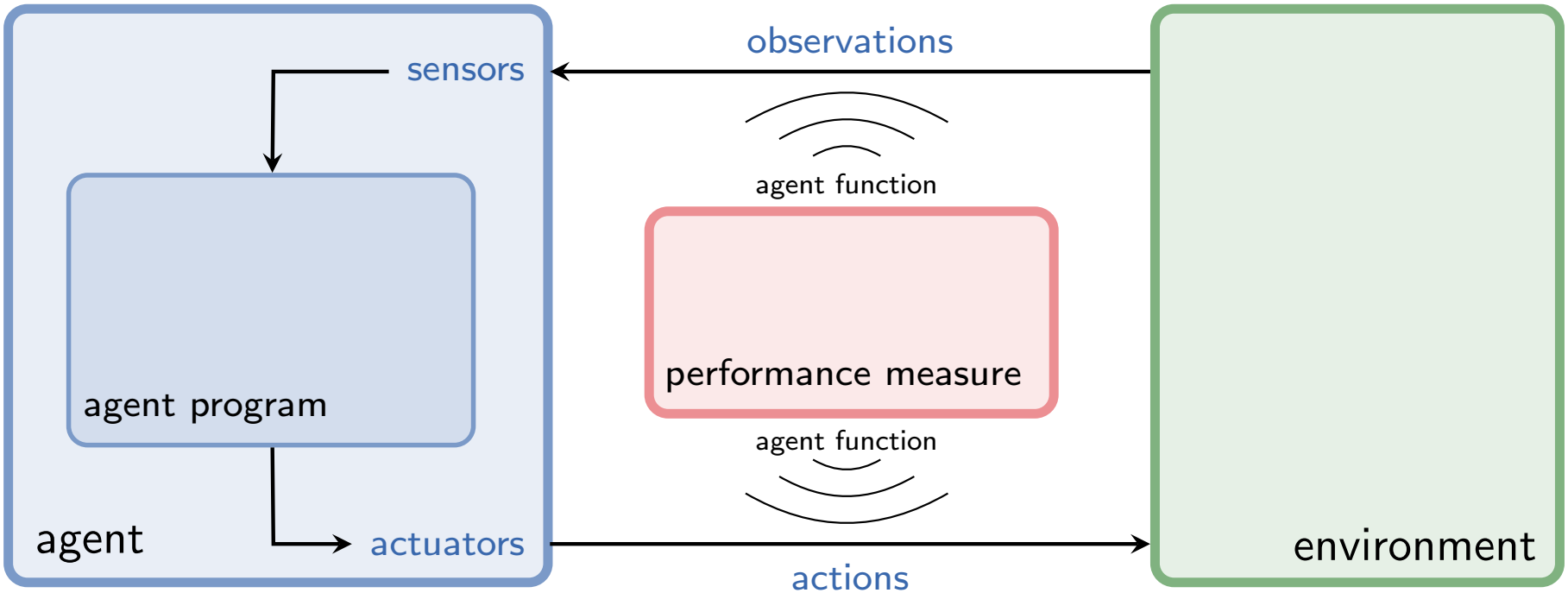
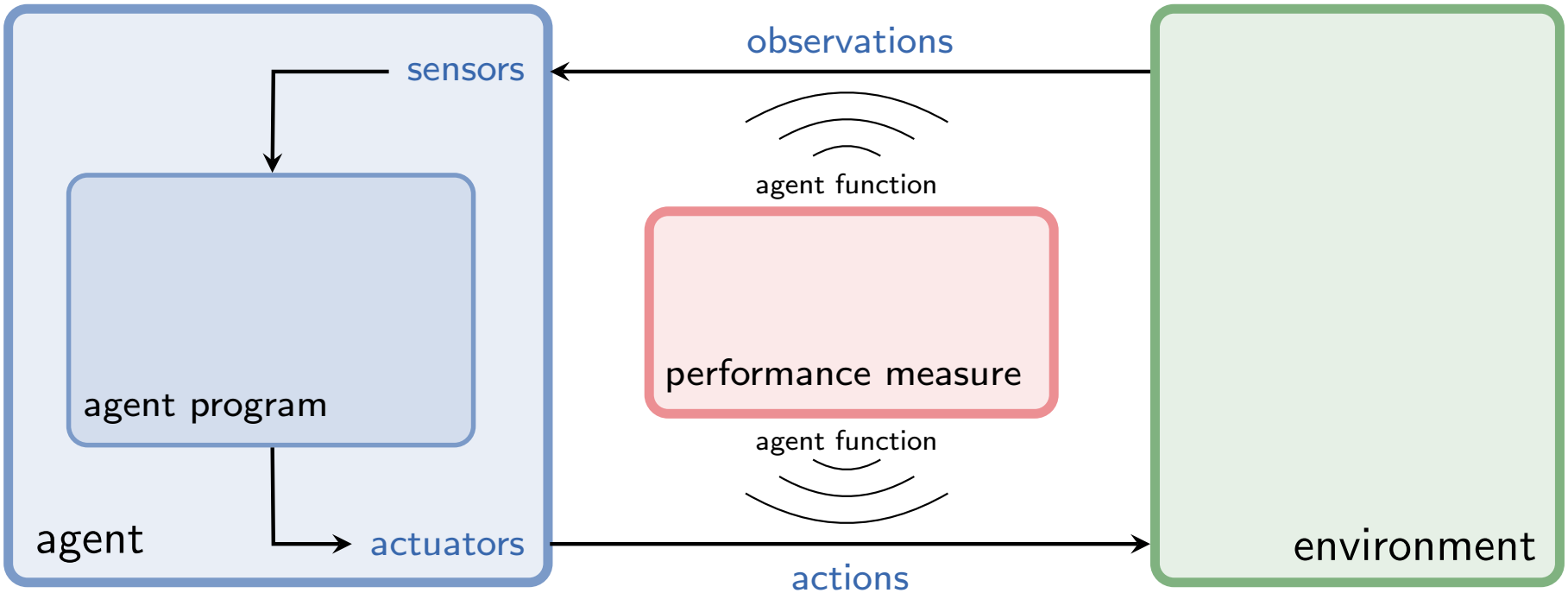
# Agent-Environment Interaction



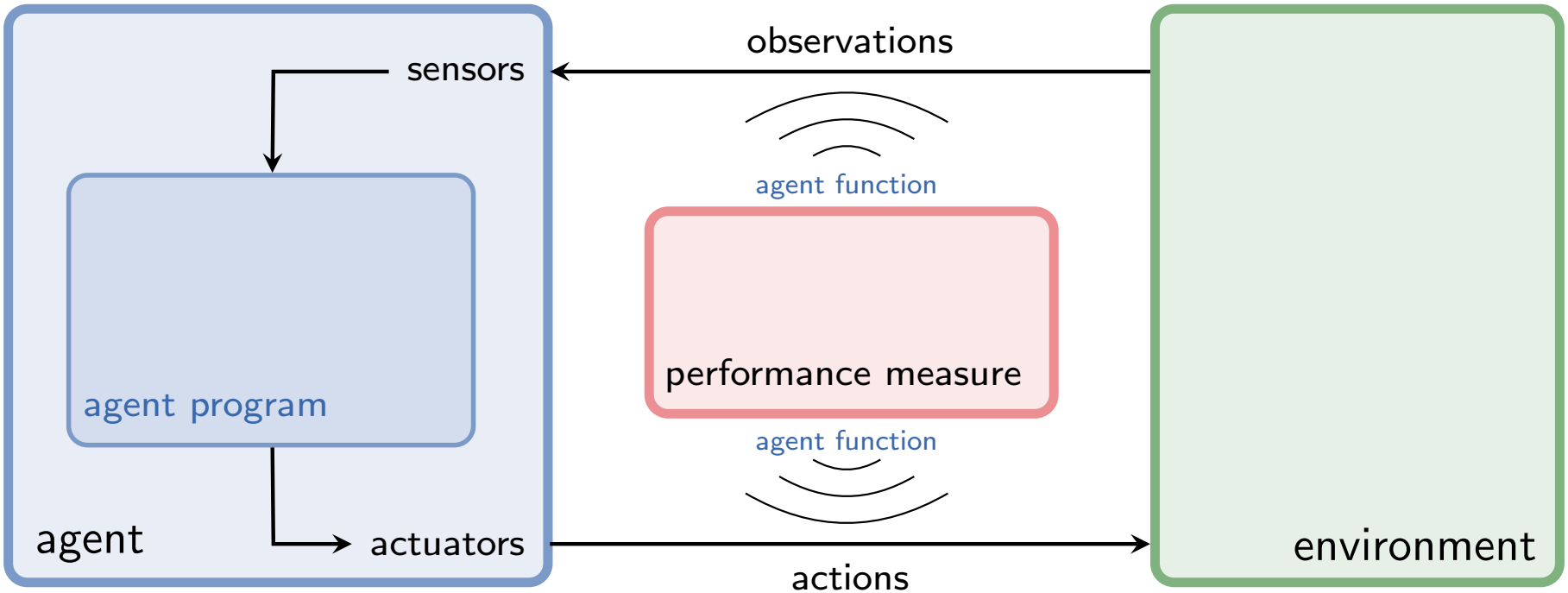

- sensors: physical entities that allow the agent to observe
- observation: data perceived by the agent's sensors
- actuators: physical entities that allow the agent to act
- action: abstract concept that affects the state of the environment

# Agent-Environment Interaction




- sensors and actuators are not relevant for the course
  ($\rightsquigarrow$ typically covered in courses on robotics)
- observations and actions describe the agent's capabilities
  (the agent model)

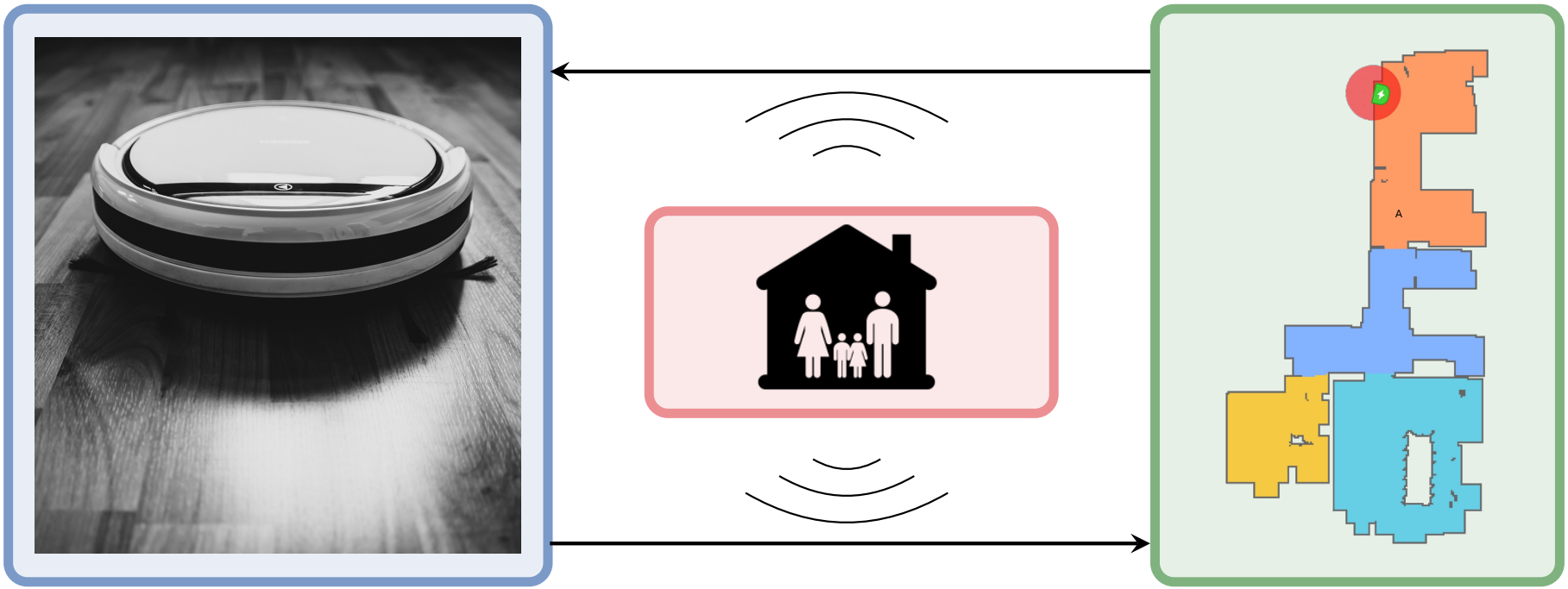
# Formalizing an Agent's Behavior



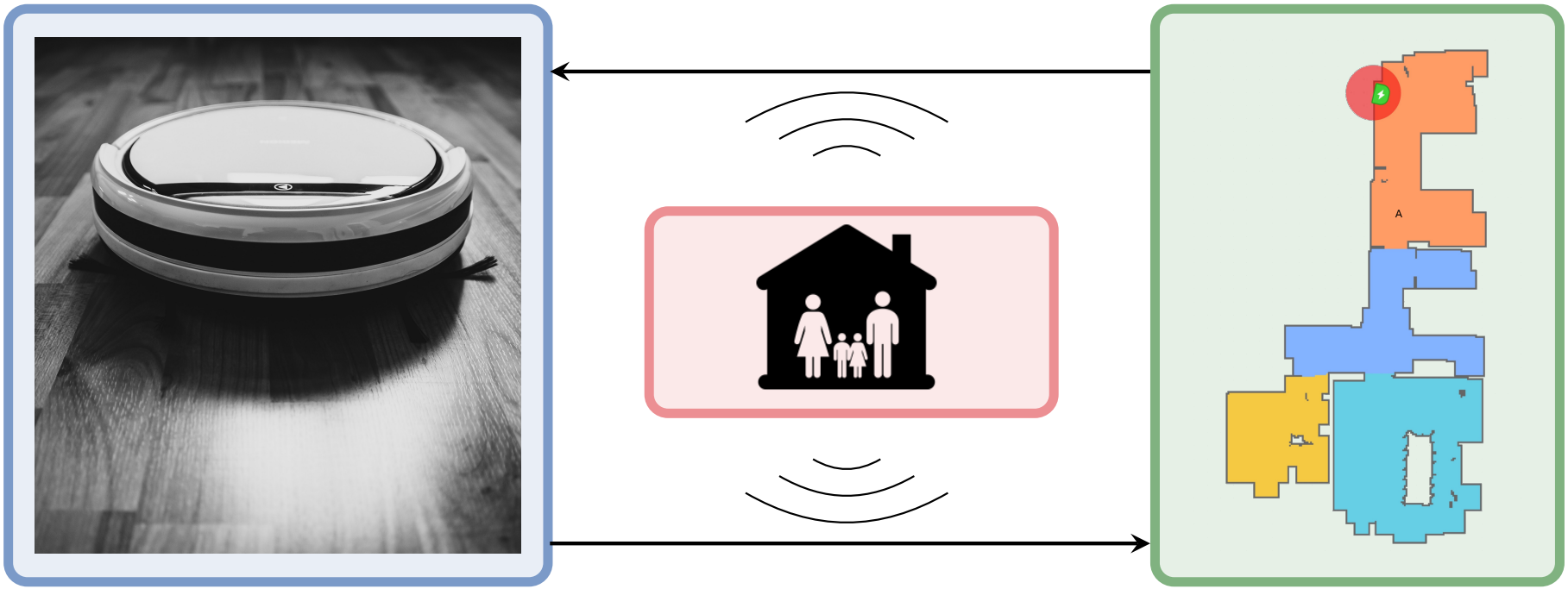

1. as agent program:
   - internal representation
   - specifics possibly unknown to outside
   - takes observation as input
   - outputs an action
   - computed on physical machine (the agent architecture)
2. as agent function:
   - external characterization
   - maps sequence of observations to (probability distribution over) actions
   - abstract mathematical formalization

# A4.2 Example

# Vacuum Domain

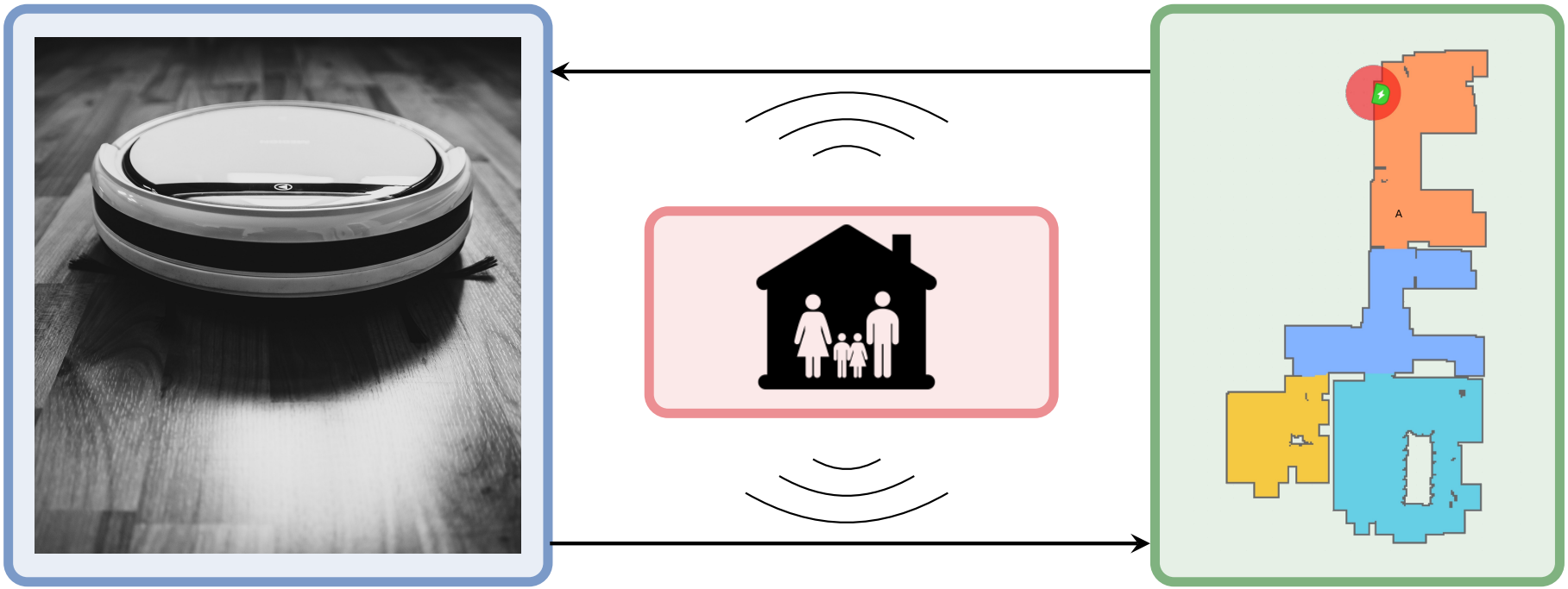


# Vacuum Agent: Sensors and Actuators



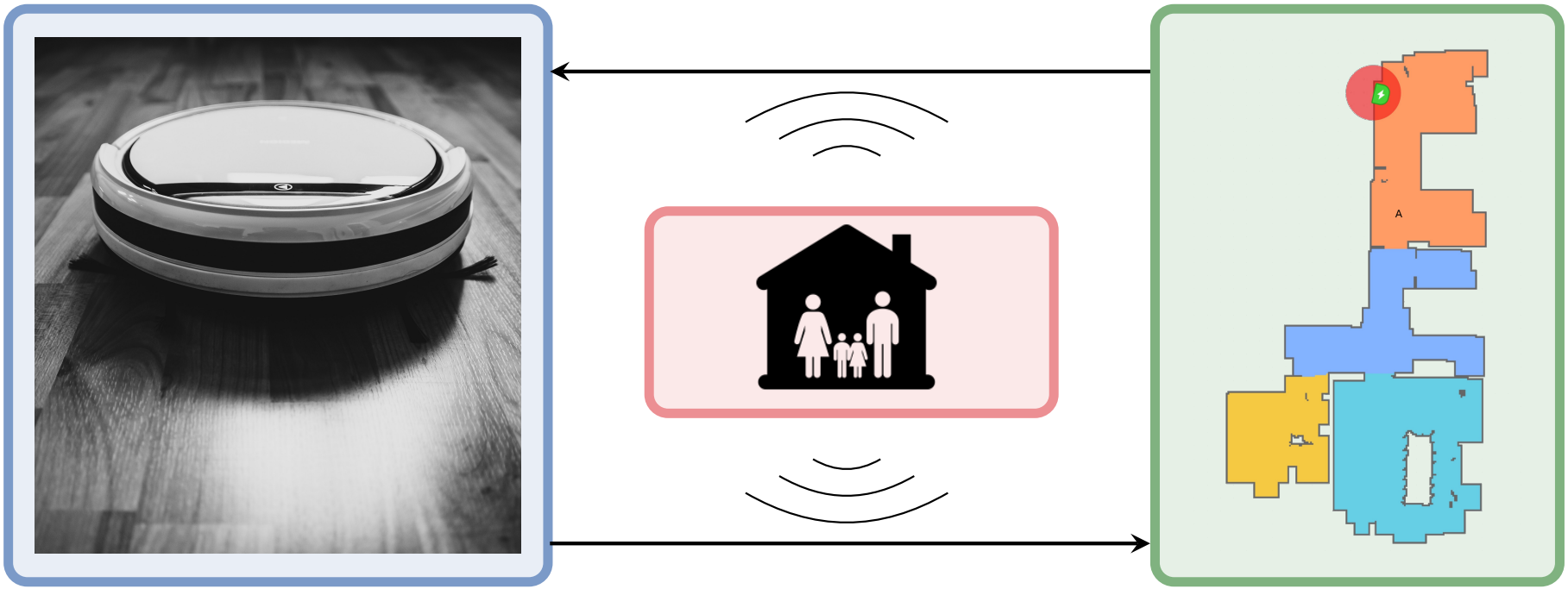

- sensors: cliff sensors, bump sensors, wall sensors, state of charge sensor, WiFi module
- actuators: wheels, cleaning system

# Vacuum Agent: Observations and Actions



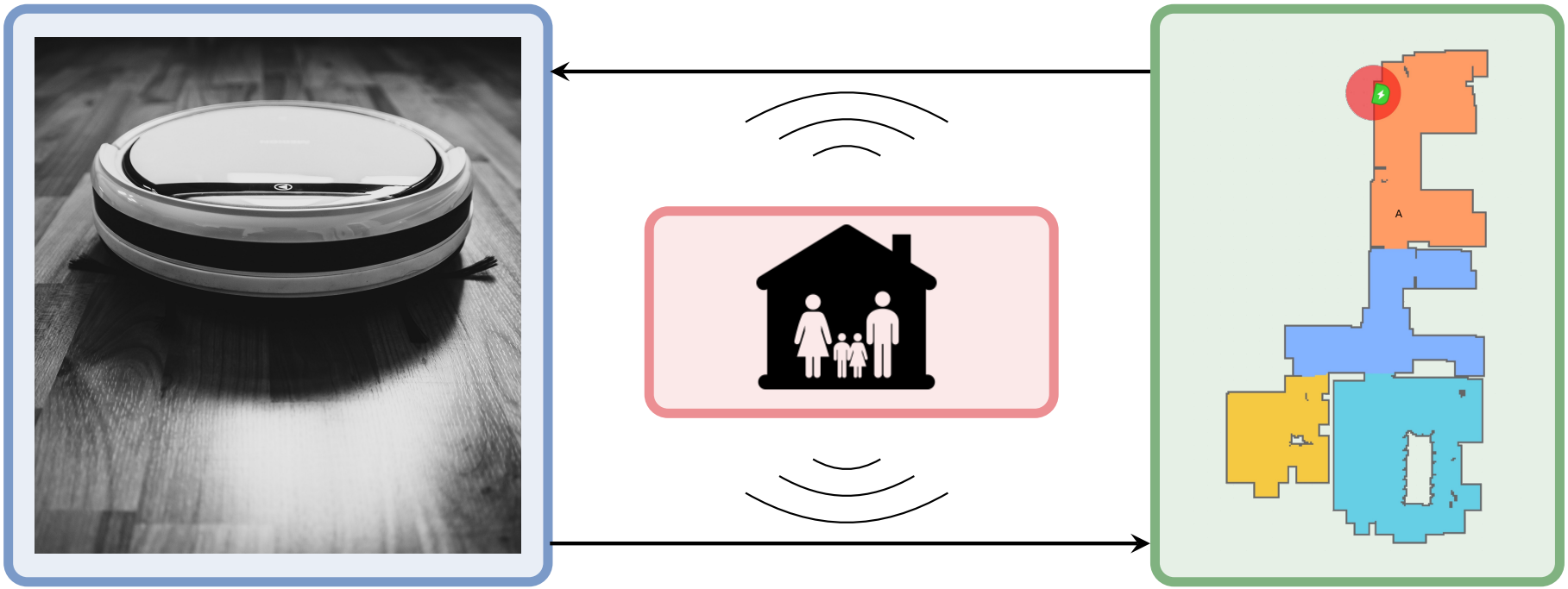

- observations: current location, dirt level of current room, presence of humans, battery charge
- actions: move-to-next-room, move-to-base, vacuum, wait

# Vacuum Agent: Agent Program



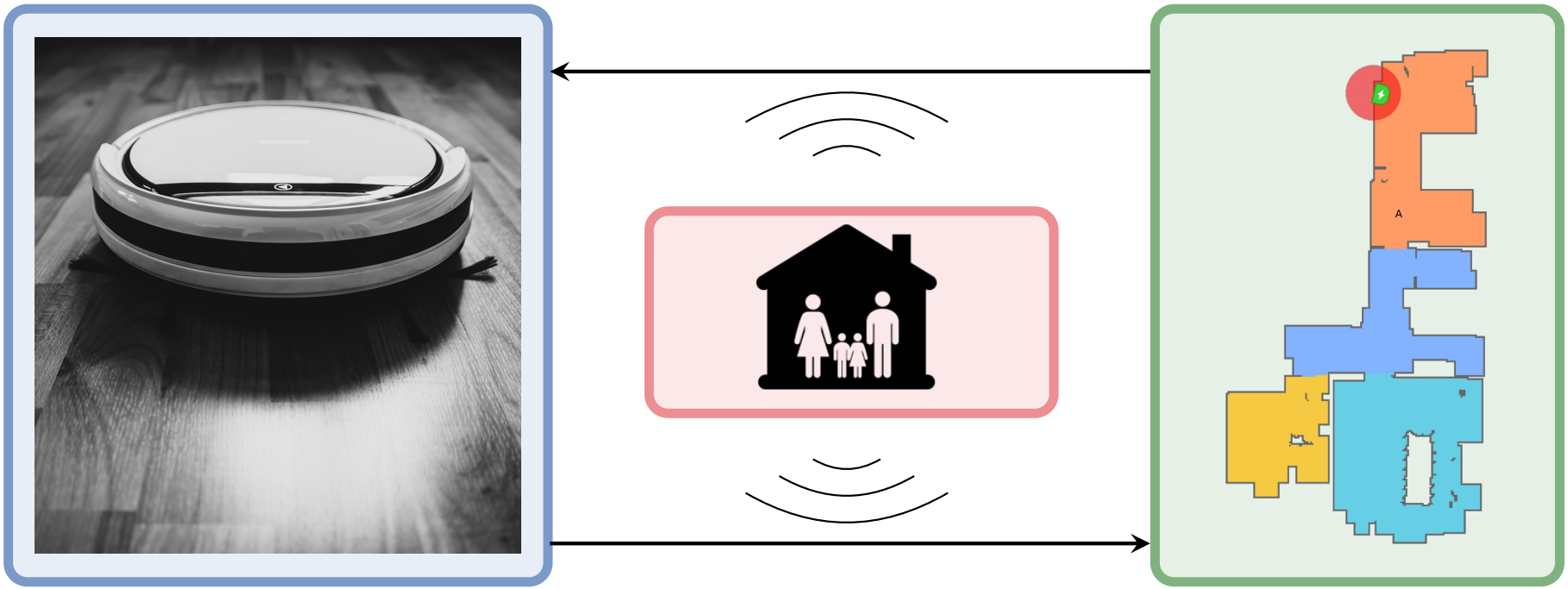
```
1 def vacuum-agent([location, dirt-level, owner-present, battery]):
2       if battery ≤ 10%: return move-to-base
3       else if owner-present = True: return move-to-next-room
4       else if dirt-level = dirty: return vacuum
5       else: return move-to-next-room
```

# Vacuum Domain: Agent Function



| observation sequence | action |
|---|---|
| $\langle$[blue, clean, False, 100%]$\rangle$ | *move-to-next-room* |
| $\langle$[blue, dirty, False, 100%]$\rangle$ | *vacuum* |
| $\langle$[blue, clean, True, 100%]$\rangle$ | *move-to-next-room* |
| ... | ... |
| $\langle$[blue, clean, False, 100%], [blue, clean, False, 90%]$\rangle$ | *move-to-next-room* |
| $\langle$[blue, clean, False, 100%], [blue, dirty, False, 90%]$\rangle$ | *vacuum* |
| ... | ... |

# Vacuum Domain: Performance Measure




potential influences on performance measure:

- cleanliness
- times vacuum-cleaned
- distance travelled
- safety
- energy consumption
- disturbance of owners

# A4.3 Rationality

# Evaluating Agent Functions

What is the right agent function?

# Rationality

rationality of an agent depends on performance measure (often: utility, reward, cost) and environment

**Perfect Rationality**

- for each possible observation sequence
- select an action which maximizes
- expected value of future performance
- given available information on observation history
- and environment

# Perfect Rationality of Our Vacuum Agent

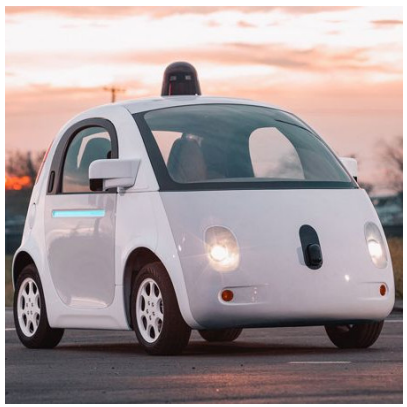
Is our vacuum agent perfectly rational?

depends on performance measure and environment, e.g.:

- Do actions reliably have the desired effect?
- Do we know the initial situation?
- Can new dirt be produced while the agent is acting?

# Performance Measure

- specified by designer
- sometimes clear, sometimes not so clear
- significant impact on
  - desired behavior
  - difficulty of problem



# Performance Measure

- specified by designer
- sometimes clear, sometimes not so clear
- significant impact on
  - desired behavior
  - difficulty of problem

# Perfect Rationality of Our Vacuum Agent

consider performance measure:

- $+1$ utility for cleaning a dirty room

consider environment:

- actions and observations reliable
- world only changes through actions of the agent

our vacuum agent is perfectly rational

# Perfect Rationality of Our Vacuum Agent

consider performance measure:

- $-1$ utility for each dirty room in each step

consider environment:

- actions and observations reliable
- world only changes through actions of the agent

our vacuum agent is not perfectly rational

# Perfect Rationality of Our Vacuum Agent

consider performance measure:

- $-1$ utility for each dirty room in each step

consider environment:

- actions and observations reliable
- yellow room may spontaneously become dirty

our vacuum agent is not perfectly rational

# Rationality: Discussion

- perfect rationality $\neq$ omniscience
  - incomplete information (due to limited observations) reduces achievable utility
- perfect rationality $\neq$ perfect prediction of future
  - uncertain behavior of environment (e.g., stochastic action effects) reduces achievable utility
- perfect rationality is rarely achievable
  - limited computational power $\rightsquigarrow$ bounded rationality

# A4.4 Summary

# Summary (1)

common metaphor for AI systems: rational agents

agent interacts with environment:

- sensors perceive observations about state of the environment
- actuators perform actions modifying the environment
- formally: agent function maps observation sequences to actions

# Summary (2)

rational agents:

- try to maximize performance measure (utility)
- perfect rationality: achieve maximal utility in expectation given available information
- for "interesting" problems rarely achievable
  $\rightsquigarrow$ bounded rationality