Foundations of Artificial Intelligence

3. Introduction: Rational Agents

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Introduction: Overview

Chapter overview: introduction

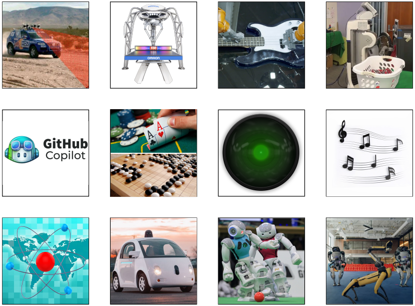
- 1. What is Artificial Intelligence?
- 2. AI Past and Present
- 3. Rational Agents
- 4. Environments and Problem Solving Methods

Systematic AI Framework

Systematic AI Framework

so far we have seen that:

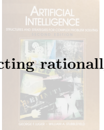
- AI systems applied to wide variety of challenges



Systematic AI Framework

so far we have seen that:

- AI systems act rationally

thinking like humans	thinking rationally
acting like humans	 **acting rationally**

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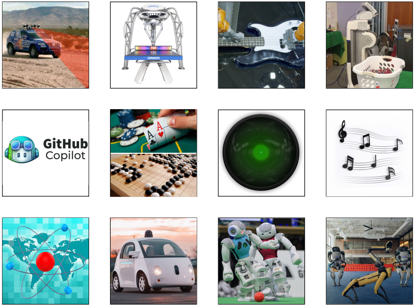

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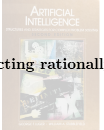
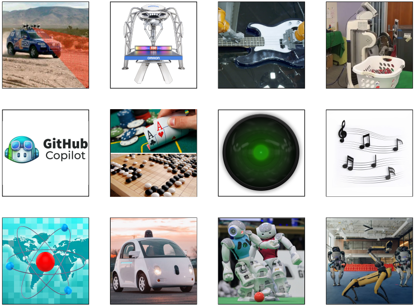
acting like humans	 **acting rationally**



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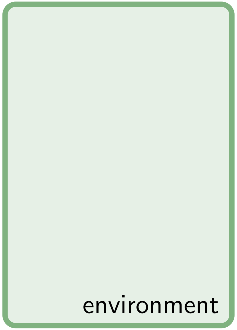

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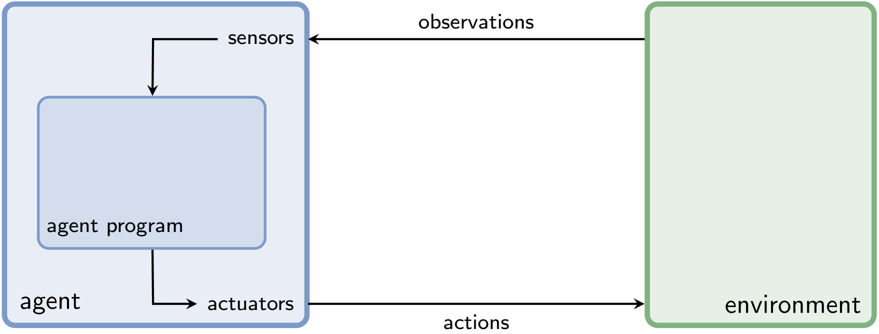

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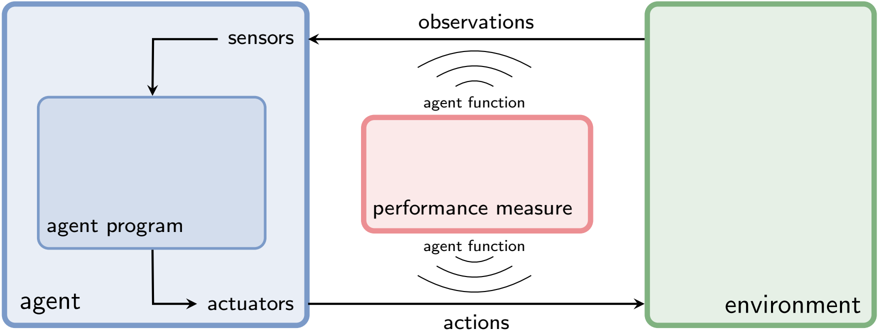
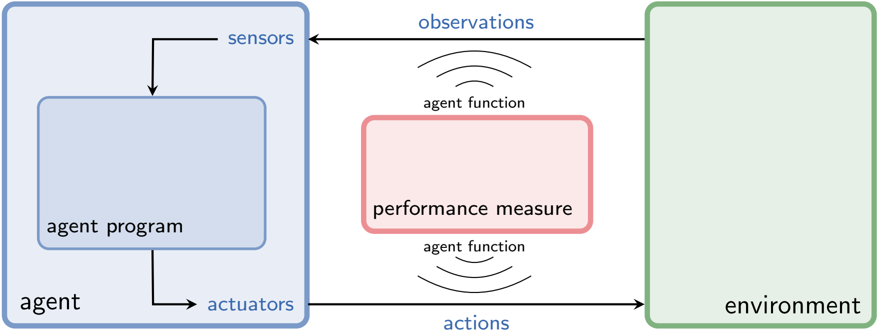


now: describe a systematic framework that

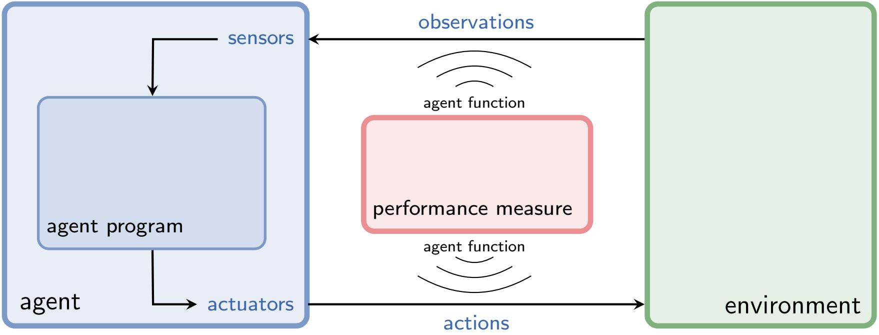
- captures this diversity of challenges
- includes an entity that is acting in the environment
- determines if the agent acts rationally in the environment

Agent-Environment Interaction



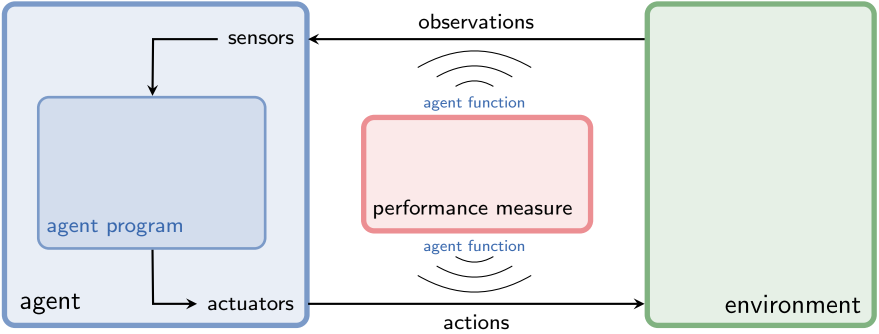
- sensors: phyisical entities that allow the agent to observe
- observation: data perceived by the agent's sensors
- actuators: phyisical entities that allow the agent to act
- action: abstract concept that affects the state of the environment

Agent-Environment Interaction



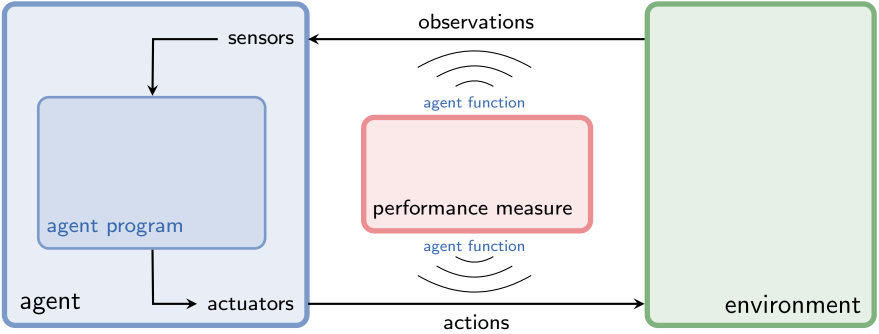
- sensors and actuators are not relevant for the course ($\rightsquigarrow$ typically covered in courses on robotics)
- observations and actions describe the agent's capabilities (the agent model)

Formalizing an Agent’s Behavior



1. as agent program:
   - internal representation
   - specifics possibly unknown to outside
2. as agent function:
   - external characterization

Formalizing an Agent's Behavior



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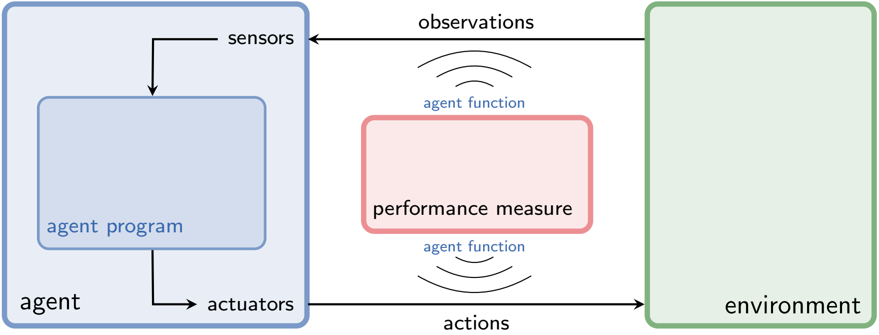
Formalizing an Agent's Behavior

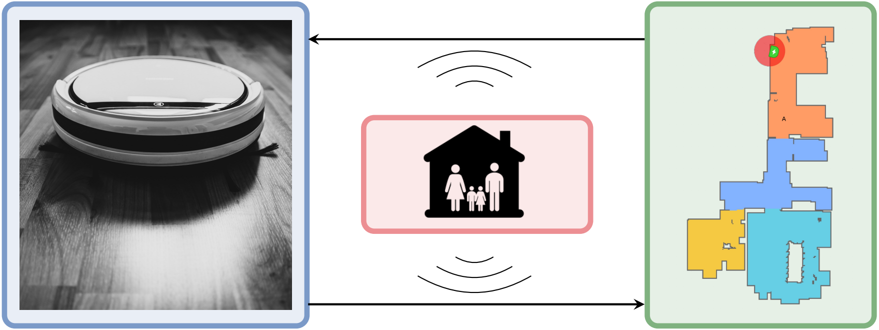


1. as agent program:
   - internal representation
   - specifics possibly unknown to outside
   - takes observation as input
   - outputs an action
   - computed on physical machine (the agent architecture)

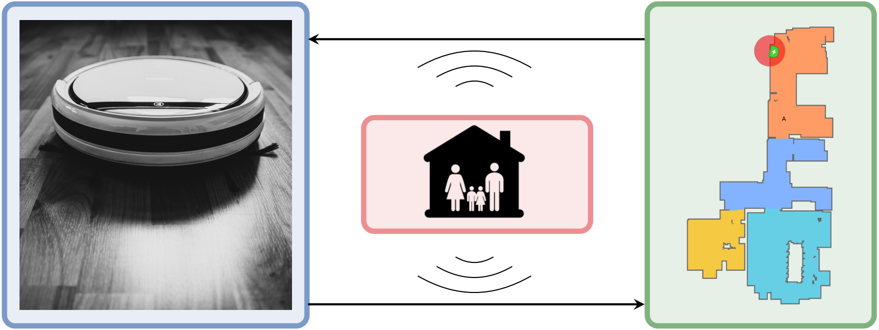
2. as agent function:
   - external characterization
   - maps sequence of observations to (probability distribution over) actions
   - abstract mathematical formalization

Example

Vacuum Domain

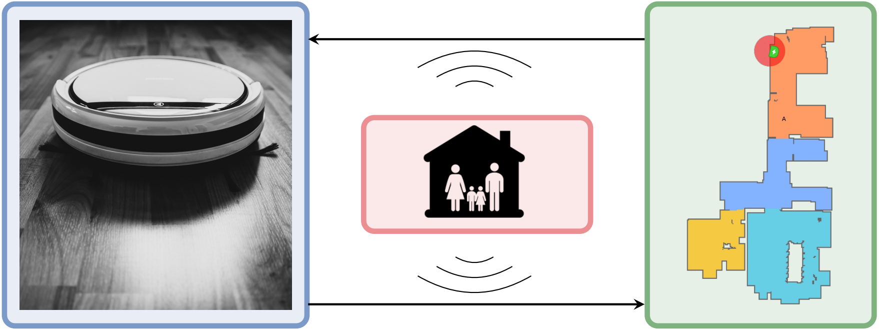


Vacuum Agent: Sensors and Actuators



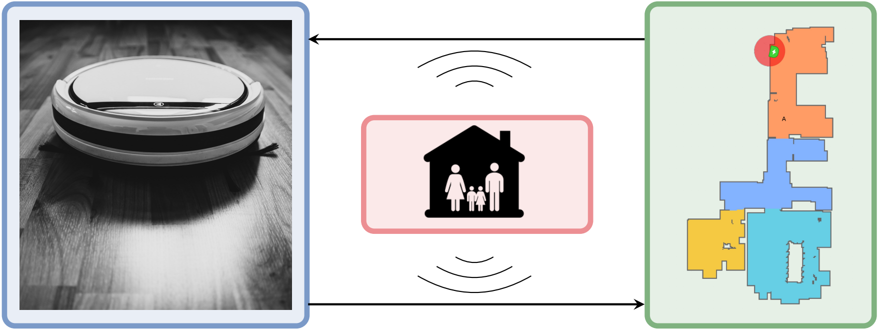
- sensors: cliff sensors, bump sensors, wall sensors, state of charge sensor, WiFi module
- actuators: wheels, cleaning system

Vacuum Agent: Observations and Actions



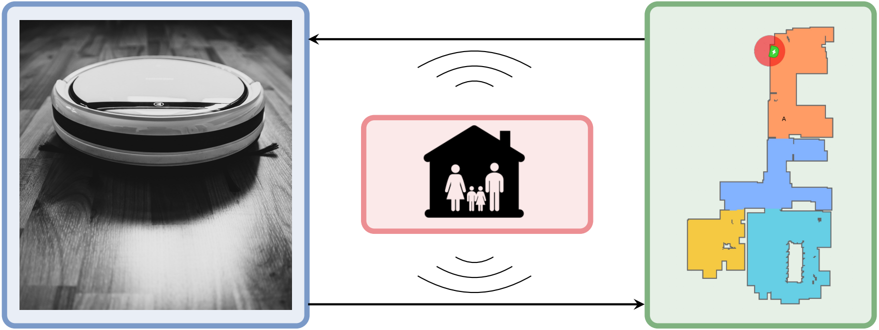
- observations: current location, cleanness of current room
  state of battery charge, presence of humans
- actions: move-to-next-room, move-to-base, vacuum, wait

Vacuum Agent: Agent Program



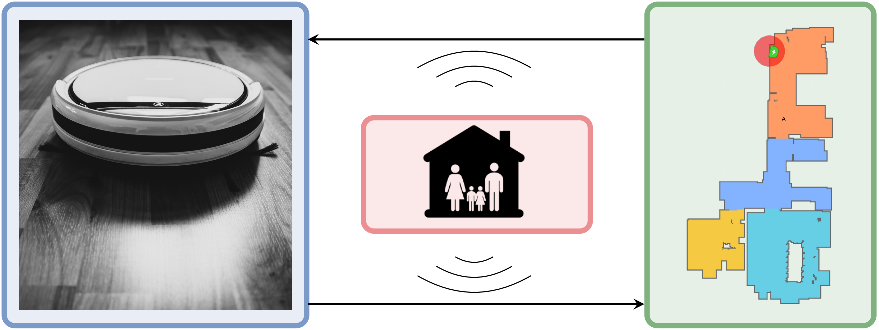
```
def vacuum-agent([$\textit{cleanness}$, $\textit{owner-present}$, $\textit{battery}$]):
        if $\textit{battery} \leq 10\%$: return $\textit{move-to-base}$
        else if $\textit{owner-present} = \text{True}$: return $\textit{move-to-next-room}$
        else if $\textit{cleanness} = \text{dirty}$: return $\textit{vacuum}$
        else: return $\textit{move-to-next-room}$
```

Vacuum Domain: Agent Function



observation sequence	action
⟨[clean, False, 100%]⟩	*move-to-next-room*
⟨[dirty, False, 100%]⟩	*vacuum*
⟨[clean, True, 100%]⟩	*move-to-next-room*
. . .	. . .
⟨[clean, False, 100%], [clean, False, 90%]⟩	*move-to-next-room*
⟨[clean, False, 100%], [dirty, False, 90%]⟩	*vacuum*
. . .	. . .

Vacuum Domain: Performance Measure



potential influences on performance measure:

- cleanliness
- times vacuum-cleaned
- distance travelled

- safety
- energy consumption
- disturbance of owners

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

*sometimes minimize, e.g. in case of costs

Perfect Rationality of Our Vacuum Agent

Is our vacuum agent perfectly rational?

Perfect Rationality of Our Vacuum Agent

Is our vacuum agent perfectly rational?

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

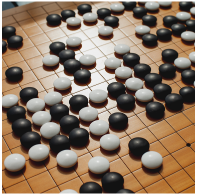
- Do actions reliably have the desired effect?
- Do we know the initial situation?
- Can new dirt be produced while the agent is acting?

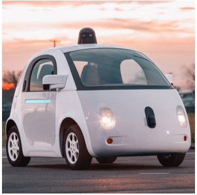
Performance Measure

- usually specified by developer

Performance Measure

- usually specified by developer
- sometimes clear,
  sometimes not so clear





Performance Measure

- usually specified by developer
- 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
- non-zero probability that yellow room becomes 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

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
- reflexive agent: agent function only based on last observation

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