

Agents and Environment

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50.021 Artificial Intelligence

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Outline & Objectives

- Understand the basic idea behind rational agents and the agent model, i.e. the PEAS description
 - Performance measure
 - Environment
 - Actuators
 - Sensors
- Understand the environment type in terms of its six characteristics
 - Observable, Deterministic, Episodic, Static, Discrete, Single-agent



Recap: Definitions of AI

- Discipline that systematizes and automates intellectual tasks to create machines that:

| | |
|-------------------|------------------|
| Think like humans | Think rationally |
| Act like humans | Act rationally |



Recap: Acting Rationally

- Rational behavior: do the right thing
- Always make the best decision given what is available (knowledge, time, resources)
- Usefulness: optimize a defined criterion
- Limitations: how to define a function/criterion measuring better or worse?
 - “criterion/function = cost efficiency?”
 - Where can it be useful?
 - What are possible risks?



What is an Agent?

- An **agent** is anything that can be viewed as **perceiving** its **environment** through **sensors** and **acting** upon that environment through **actuators**



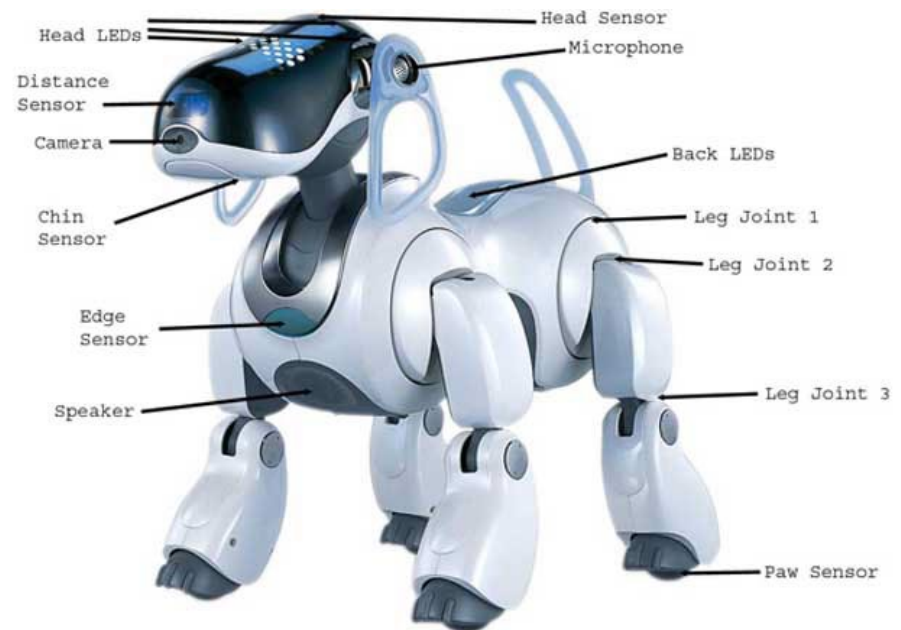
What is an Agent?

- An **agent** is anything that can be viewed as **perceiving** its **environment** through **sensors** and **acting** upon that environment through **actuators**
- E.g., Human agent
 - Sensors: eyes, ears, and other organs
 - Actuators: hands, legs, mouth, and other body parts



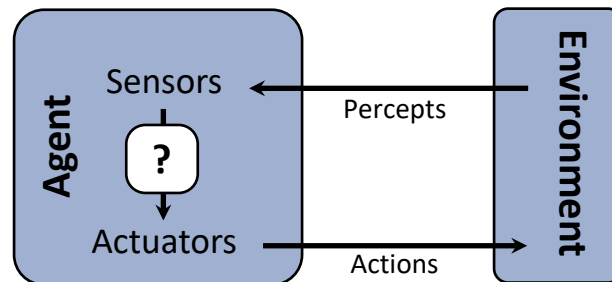
What is an Agent?

- An **agent** is anything that can be viewed as **perceiving** its **environment** through **sensors** and **acting** upon that environment through **actuators**
- E.g., Robotic agent
 - Sensors: cameras and infrared range finders
 - Actuators: various motors, limbs, etc



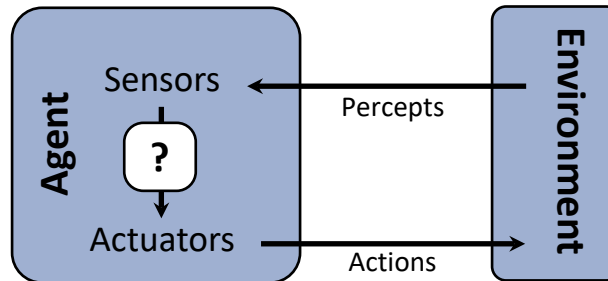
The Agent Model

- **Percepts**/observations of the environment, made by sensors
- **Actions** which may affect the environment, made by actuators
- **Environment** in which the agent exists
- **Performance measure** of the desirability of environment states



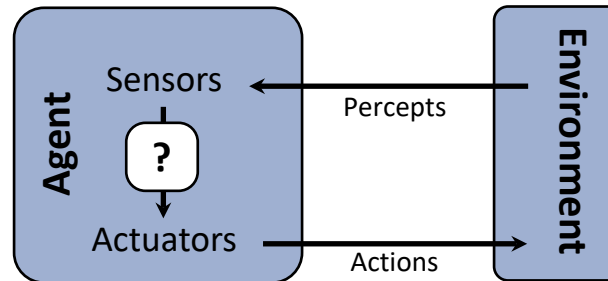
Rational Agents

- A **rational agent** selects actions that maximize its (expected) **utility**.
 - I.e., Perceives and acts to optimize a performance measure
- Characteristics of the **percepts**, **environment**, and **action space** dictate techniques for selecting rational actions



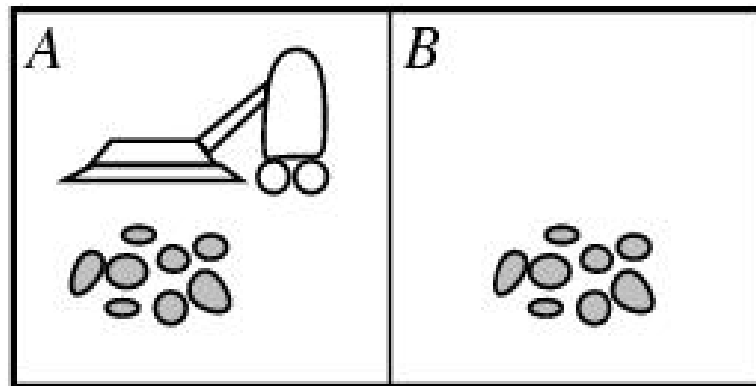
Rational Agents

- An agent is specified by an **agent function** $f: P \rightarrow A$ that maps a sequence of percept vectors P to an action a from a set A :
 - $P = [p_0, p_1, \dots, p_t]$
 - $A = \{a_0, a_1, \dots, a_k\}$

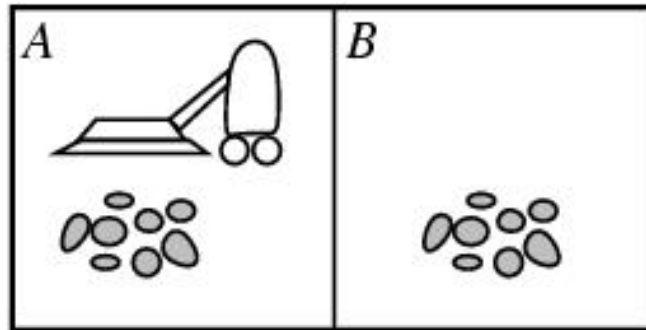


Vacuum-cleaner world

- Environment: square A and B
- Percepts: [location and content] e.g. *[A, Dirty]*
- Actions: left, right, suck, and no-op



Vacuum-cleaner world

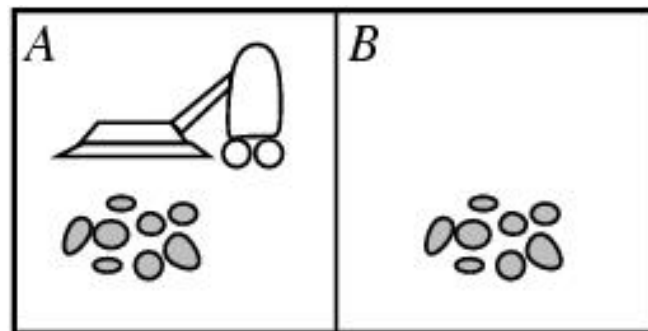


| Percept sequence | Action |
|-----------------------|--------|
| [A,Clean] | Right |
| [A, Dirty] | Suck |
| [B, Clean] | Left |
| [B, Dirty] | Suck |
| [A, Clean],[A, Clean] | Right |
| [A, Clean],[A, Dirty] | Suck |
| ... | ... |



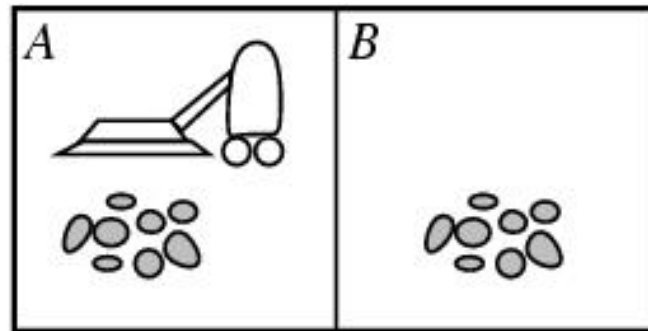
Vacuum-cleaner world

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



Vacuum-cleaner world

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



- *However, what is the right function to implement?*



Concept of Rationality

- A rational agent is one that does the right thing.
 - Every entry in the table is filled out correctly.
 - But what if the table is infinitely large?

| 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 |
| ... | ... |



Concept of Rationality

- A rational agent is one that does the right thing.
 - Every entry in the table is filled out correctly.
- What is the right thing?
 - Approximation: the most successful agent.
 - Measure of success? Performance measure?



Concept of Rationality

- A rational agent is one that does the right thing.
 - Every entry in the table is filled out correctly.
- What is the right thing?
 - Approximation: the most successful agent.
 - Measure of success? Performance measure?
- Performance measure should be objective
 - E.g., +1 for each cleaned location
 - E.g., +5 per cleaned location, -1 per move
 - ...



Concept of Rationality

- Performance measure should be based on a desired state in the environment instead of how the agents should behave.
- Compare between the following performance measures
 - Total time spent cleaning
 - Total number of clean tiles
- How do you think an agent will behave based on these performance measures?



Concept of Rationality

- Performance measure should be based on a desired state in the environment instead of how the agents should behave.
- Compare between the following performance measures
 - Total time spent cleaning
 - Total number of clean tiles
- How do you think an agent will behave based on these performance measures?
 - Total time spent cleaning – Agent behavior
 - E.g., +1 for each cleaning performed (regardless of dirt condition)
 - Total number of clean tiles – Environment state
 - E.g., +1 for each clean location



Concept of Rationality

- What is rational at a given time depends on four things:
 - **P**erformance measure
 - **P**rior **E**nvironment knowledge
 - **A**ctions
 - Percept sequence to date (**S**ensors)
- Definition: A rational agent chooses whichever action maximizes the **expected value** of the performance measure given the percept sequence to date and prior environment knowledge.



Limits of Rationality

- The ideal case is to have an agent maximize its actual performance
 - However, this is almost impossible for real-life scenarios
- Limitations
 - Rationality \neq omniscience
 - Percepts may not provide all the required information
 - Rationality \neq clairvoyant
 - Actual outcome of actions may not be as expected
- Thus, we aim for a “bounded” rationality based on expected performance, not actual performance
 - Bounded based on these limitations



Environment Types

- The task environment largely determines rational agent design, i.e., the PEAS description:
 - Performance measure
 - Environment
 - Actuators
 - Sensors
- PEAS is akin to a problem specification for the agent to solve
 - Can you think of a few examples?



PEAS

- Agent: Medical diagnosis system
 - Performance measure: ?
 - Environment: ?
 - Actuators: ?
 - Sensors: ?



PEAS

- Agent: Medical diagnosis system
 - Performance measure: Healthy patient, minimize costs, lawsuits
 - Environment: Patient, hospital, staff
 - Actuators: Screen display (questions, tests, diagnoses, treatments, referrals)
 - Sensors: Keyboard (entry of symptoms, findings, patient's answers)



PEAS

- Agent: Automated packing robot
 - Performance measure: ?
 - Environment: ?
 - Actuators: ?
 - Sensors: ?



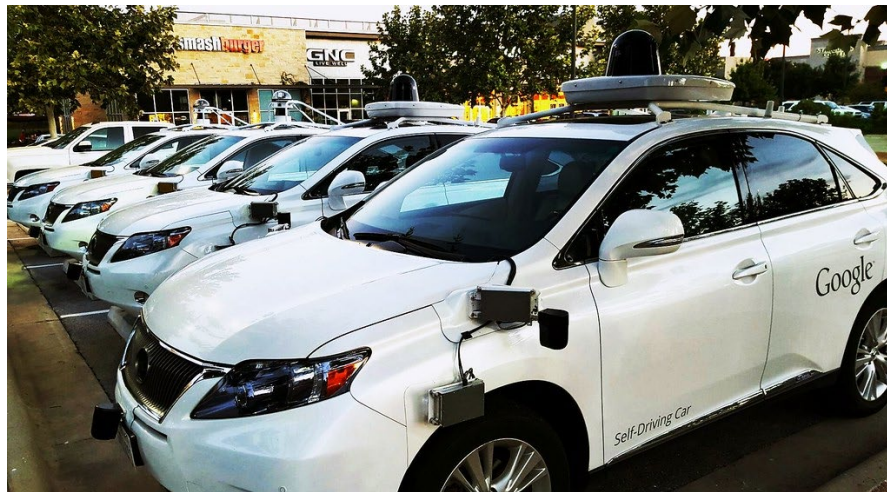
PEAS

- Agent: Automated packing robot
 - Performance measure: Percentage of items correctly packed
 - Environment: Conveyor belt with parts, bins
 - Actuators: Jointed arm and hand
 - Sensors: Camera, joint angle sensors



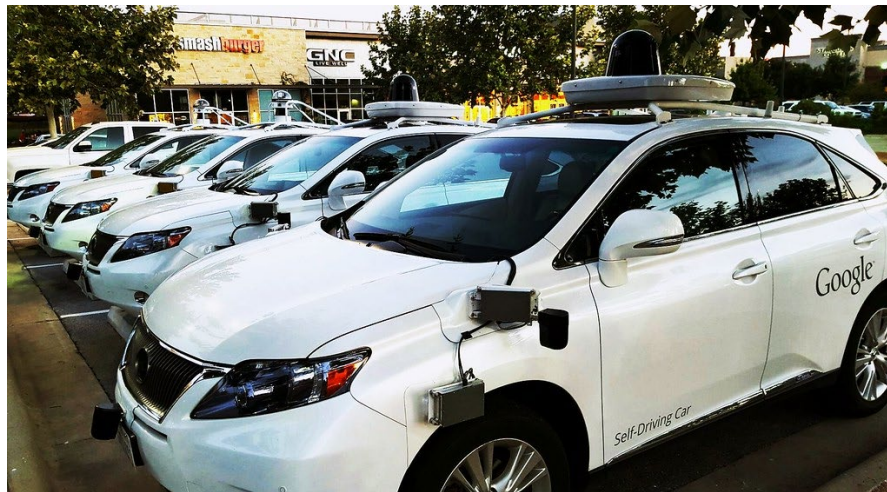
PEAS

- Agent: Autonomous vehicle
 - Performance measure: ?
 - Environment: ?
 - Actuators: ?
 - Sensors: ?



PEAS

- Agent: Autonomous vehicle
 - Performance measure: Safety, destination, profits, legality, comfort
 - Environment: Streets/freeways, other traffic, pedestrians, weather,, ...
 - Actuators: Steering, accelerating, brake, horn, speaker/display,...
 - Sensors: Video, sonar, speedometer, engine sensors, keyboard, GPS, ...



Overview of Environment

- Fully Observable vs Partially Observable? Agent is aware of complete state of environment
- Deterministic vs Stochastic? Next state of environment is based on agent's action on current states
- Episodic vs Sequential? Choice of agent's action in current "episode" is not based on previous "episodes"
- Static vs Dynamic? Environment does not change while agent is considering actions
- Discrete vs Continuous? A distinct number of percepts and actions
- Single Agent vs Multi Agent? Only a single agent acting in the same environment



Environment Types

- **Fully observable** (vs. partially observable): An agent's sensors give it access to the complete state of the environment at each point in time.
- **Deterministic** (vs. stochastic): The next state of the environment is completely determined by the current state and the action executed by the agent.
 - If the environment is deterministic except for the actions of other agents, then the environment is **strategic**
- **Episodic** (vs. sequential): 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.



Environment Types

- **Static** (vs. dynamic): The environment is unchanged while an agent is deliberating.
 - (The environment is **semidynamic** if the environment itself does not change with the passage of time but the agent's performance score does)
- **Discrete** (vs. continuous): A limited number of distinct, clearly defined percepts and actions.
- **Single agent** (vs. multiagent): An agent operating by itself in an environment.



Exercise: Environment Types

| Environment Type | Solitaire | Crossword Puzzle | Online Shopping | Basketball |
|------------------|------------|------------------|-----------------|------------------|
| Observable? | fully | fully | partially | fully |
| Deterministic? | yes | yes | yes | maybe? strategic |
| Episodic? | sequential | sequential | sequential | sequential |
| Static? | yes | yes | dynamic | dynamic |
| Discrete? | yes | yes | yes | continuous |
| Single-agent? | yes | yes | no | no |



Exercise: Environment Types

- Fully vs. partially observable: an environment is full observable when the sensors can detect all aspects that are relevant to the choice of action.

| Environment Type | Solitaire | Crossword Puzzle | Online Shopping | Basketball |
|------------------|-----------|------------------|-----------------|------------|
| Observable? | Fully | Fully | Partial | Partial |
| Deterministic? | | | | |
| Episodic? | | | | |
| Static? | | | | |
| Discrete? | | | | |
| Single-agent? | | | | |



Exercise: Environment Types

- Deterministic vs. stochastic: if the next environment state is completely determined by the current state the executed action then the environment is deterministic.

| Environment Type | Solitaire | Crossword Puzzle | Online Shopping | Basketball |
|------------------|-----------|------------------|-----------------|------------|
| Observable? | Fully | Fully | Partial | Partial |
| Deterministic? | Yes | Yes | Yes | No |
| Episodic? | | | | |
| Static? | | | | |
| Discrete? | | | | |
| Single-agent? | | | | |



Exercise: Environment Types

- Episodic vs. sequential: In an episodic environment the agent's experience can be divided into atomic steps where the agents perceives and then performs a single action. The choice of action depends only on the episode itself

| Environment Type | Solitaire | Crossword Puzzle | Online Shopping | Basketball |
|------------------|-----------|------------------|-----------------|------------|
| Observable? | Fully | Fully | Partial | Partial |
| Deterministic? | Yes | Yes | Yes | No |
| Episodic? | No | No | No | No |
| Static? | | | | |
| Discrete? | | | | |
| Single-agent? | | | | |



Exercise: Environment Types

- Static vs. dynamic: If the environment can change while the agent is choosing an action, the environment is dynamic. Semi-dynamic if the agent's performance changes even when the environment remains the same.

| Environment Type | Solitaire | Crossword Puzzle | Online Shopping | Basketball |
|------------------|-----------|------------------|-----------------|------------|
| Observable? | Fully | Fully | Partial | Partial |
| Deterministic? | Yes | Yes | Yes | No |
| Episodic? | No | No | No | No |
| Static? | Yes | Yes | Semi | No |
| Discrete? | | | | |
| Single-agent? | | | | |



Exercise: Environment Types

- Discrete vs. continuous: This distinction can be applied to the state of the environment, the way time is handled and to the percepts/actions of the agent.

| Environment Type | Solitaire | Crossword Puzzle | Online Shopping | Basketball |
|------------------|-----------|------------------|-----------------|------------|
| Observable? | Fully | Fully | Partial | Partial |
| Deterministic? | Yes | Yes | Yes | No |
| Episodic? | No | No | No | No |
| Static? | Yes | Yes | Semi | No |
| Discrete? | Yes | Yes | Yes | No |
| Single-agent? | | | | |



Exercise: Environment Types

- Single vs. multi-agent: Does the environment contain other agents who are also maximizing some performance measure that depends on the current agent's actions?

| Environment Type | Solitaire | Crossword Puzzle | Online Shopping | Basketball |
|------------------|-----------|------------------|-----------------|------------|
| Observable? | Fully | Fully | Partial | Partial |
| Deterministic? | Yes | Yes | Yes | No |
| Episodic? | No | No | No | No |
| Static? | Yes | Yes | Semi | No |
| Discrete? | Yes | Yes | Yes | No |
| Single-agent? | Yes | Yes | No | No |



Environment Types

- The real world is (mostly):
 - Partially observable
 - Stochastic
 - Sequential
 - Dynamic
 - Continuous
 - Multi-agent
- This also happens to be the hardest environment!



Environment Types

- The simplest environment is:
 - Fully observable
 - Deterministic
 - Episodic
 - Static
 - Discrete
 - Single-agent
- For the next part on search, we will assume this simple environment



Next Lecture

- Problem Formulation
- General Search

