

# Agents and Environment

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50.021 Artificial Intelligence

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# Outline & Objectives

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- 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

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

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



# Recap: Acting Rationally

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- 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?

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- 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?

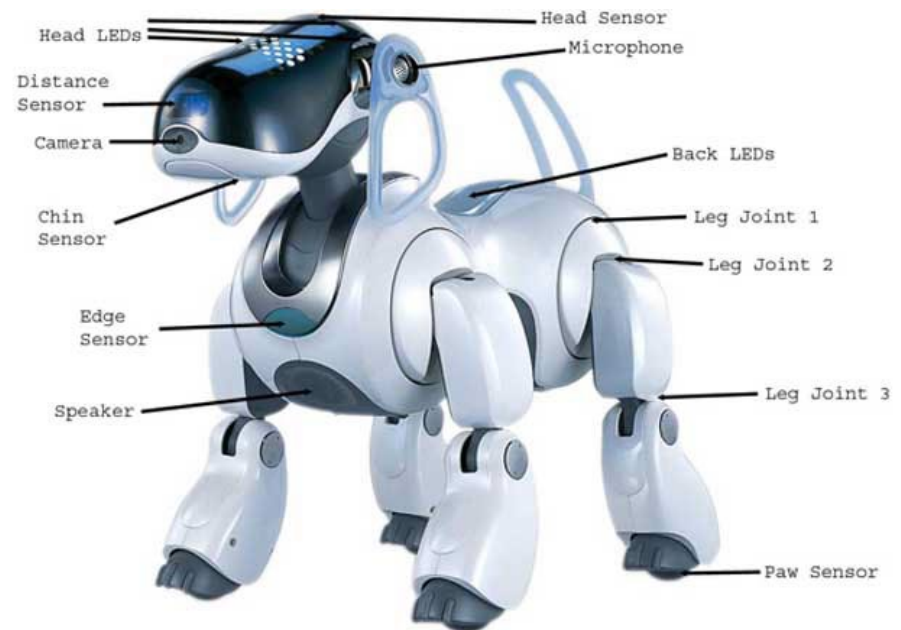
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- An **agent** is anything that can be viewed as **perceiving** its **environment** through **sensors** and **acting** upon that environment through **actuators**
- E.g., Human agent
  - Sensors: eyes, ears, and other organs
  - Actuators: hands, legs,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



# What is an Agent?

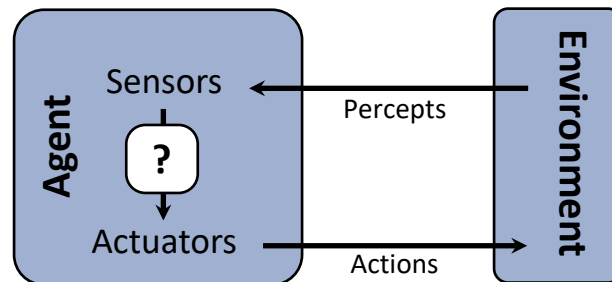
- An **agent** is anything that can be viewed as **perceiving** its **environment** through **sensors** and **acting** upon that environment through **actuators**
- E.g., Robotic agent
  - Sensors: cameras and infrared range finders
  - Actuators: various motors, limbs, etc



# The Agent Model

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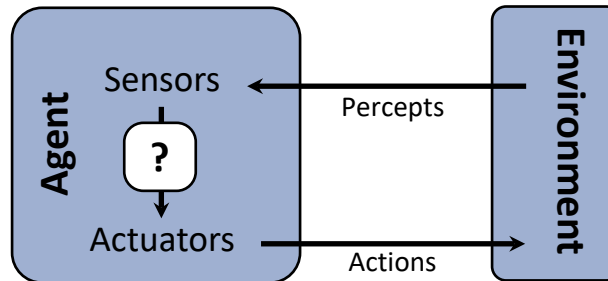
- **Percepts**/observations of the environment, made by sensors
- **Actions** which may affect the environment, made by actuators
- **Environment** in which the agent exists
- **Performance measure** of the desirability of environment states





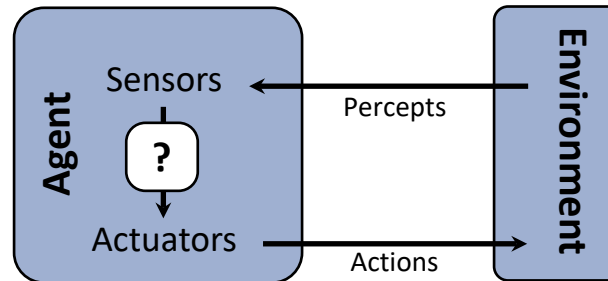
# Rational Agents

- 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

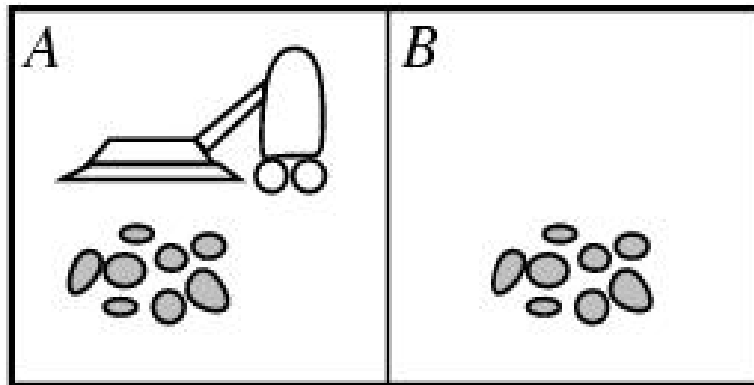
- An agent is specified by an **agent function**  $f: P \rightarrow A$  that maps a sequence of percept vectors  $P$  to an action  $a$  from a set  $A$ :
  - $P = [p_0, p_1, \dots, p_t]$
  - $A = \{a_0, a_1, \dots, a_k\}$



# Vacuum-cleaner world

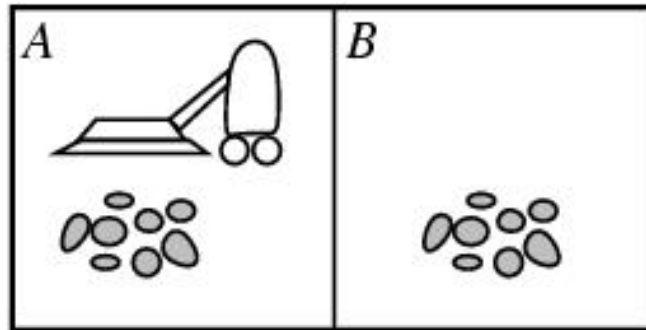
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- Environment: square A and B
- Percepts: [location and content] e.g. *[A, Dirty]*
- Actions: left, right, suck, and no-op



# Vacuum-cleaner world

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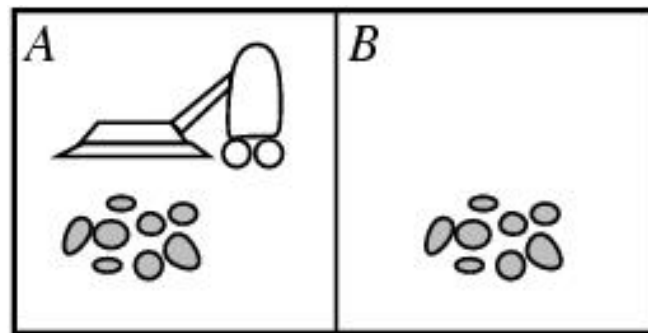
| Percept sequence      | Action |
|-----------------------|--------|
| [A,Clean]             | Right  |
| [A, Dirty]            | Suck   |
| [B, Clean]            | Left   |
| [B, Dirty]            | Suck   |
| [A, Clean],[A, Clean] | Right  |
| [A, Clean],[A, Dirty] | Suck   |
| ...               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



# Vacuum-cleaner world

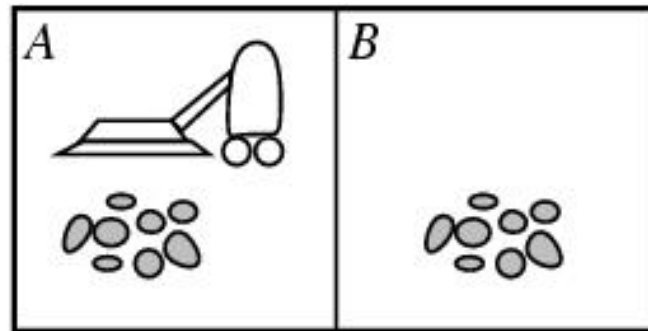
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function REFLEX-VACUUM-AGENT ( $[location, status]$ ) return an action  
  if  $status == Dirty$  then return *Suck*  
  else if  $location == A$  then return *Right*  
  else if  $location == B$  then return *Left*



# 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

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- 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

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- 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

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- 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

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- 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

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- 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

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- 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

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- 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

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- 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

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



# PEAS

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- 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

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



# PEAS

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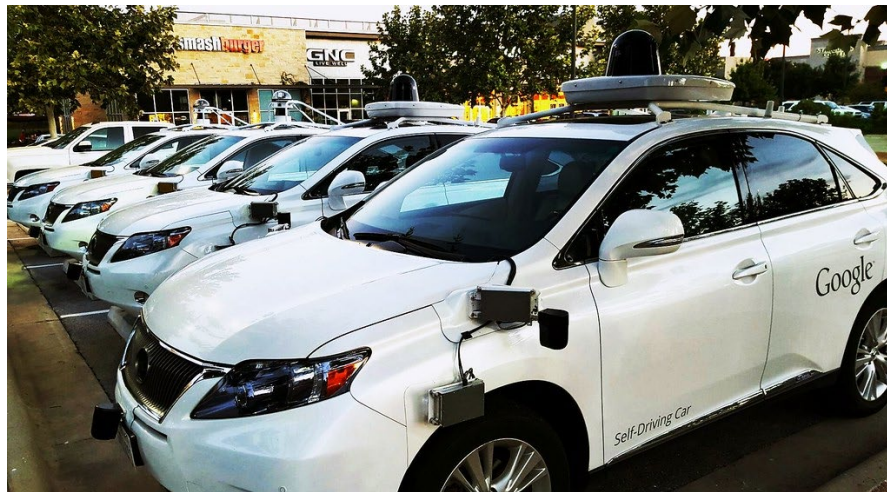
- Agent: Automated packing robot
  - Performance measure: Percentage of items correctly packed
  - Environment: Conveyor belt with parts, bins
  - Actuators: Jointed arm and hand
  - Sensors: Camera, joint angle sensors



# PEAS

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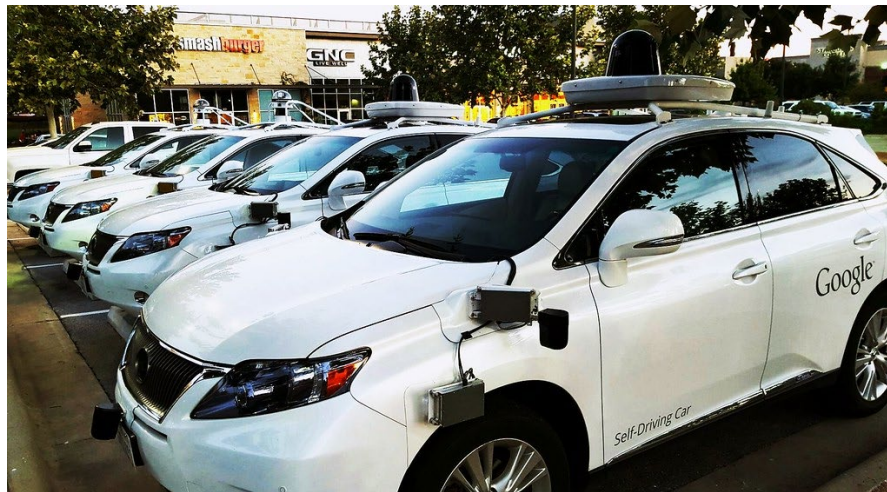
- Agent: Autonomous vehicle
  - Performance measure: ?
  - Environment: ?
  - Actuators: ?
  - Sensors: ?



# PEAS

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- 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

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- 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

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- **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

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- **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

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





# 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

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



# Environment Types

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- 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

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- Problem Formulation
- General Search

