Representational Dimensions

CMPUT 366: Intelligent Systems

P&M Chapter 1

Lecture Outline

1. Recap
2. Agents
3. Representations
4. Dimensions of representation

Recap: Course Essentials

Course information: https://eclass.srv.ualberta.ca/course/view.php?id=76608

- This is the main source for information about the class
- Slides, readings, assignments, deadlines

Lectures: Mondays, Wednesdays, and Fridays, 11:00-11:50am on Zoom

- Lectures will be recorded and posted on eClass

eClass Discussion forum for **public** questions about assignments, lecture material, etc.

Email: james.wright@ualberta.ca for **private** questions

- (health problems, inquiries about grades)

Office hours: After lectures on Mondays & Fridays, or by appointment

- TA office hours will be announced on Friday

What is Artificial Intelligence?

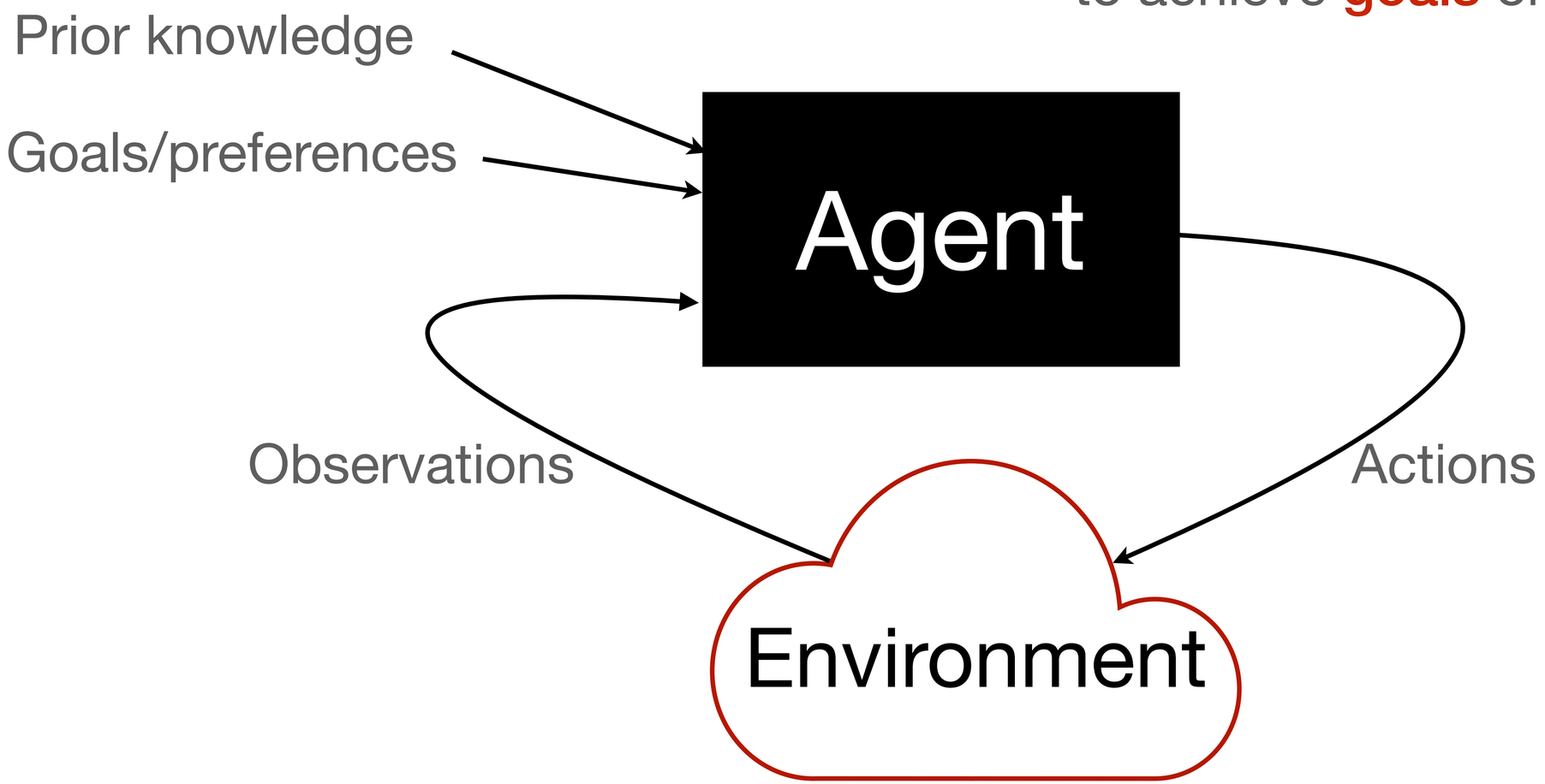
	Reasoning	Acting
Like Humans	1. Think like humans	2. Act like humans
Rationally	3. Think rationally	4. Act rationally

Questions:

1. Which of these definitions do you find most **convincing**?
2. What is **missing** from these definitions?

Recap: Agents

An **agent** is a system that **acts** in an **environment** to achieve **goals** or optimize **preferences**.

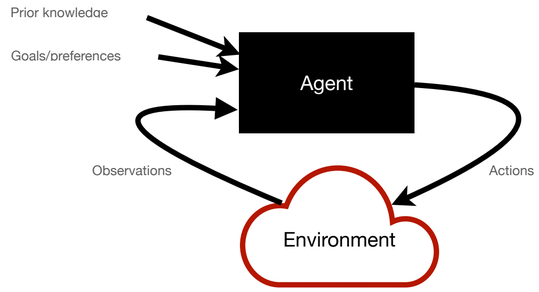


Examples

Which of these things are **agents**?

- A rock
- A tree
- A bird
- A car
- A decision assistant (previously: "expert system")
- A self-driving car
- A child
- An adult

Representations



- **Knowledge**: Information about a domain useful for **solving problems** in that domain
- To use knowledge, a computational agent needs to encode it into a set of data structures called a **representation**
- Representations are about the **environment**:
  - What kinds of **states** can the world be in? How should we denote them?
  - What kind of **information** do we get about the current and past states? How certain can our **beliefs** be?
  - **Dynamics:** How does the environment change based on our actions? Are the changes **deterministic**, or **stochastic**?

Representations: Wishlist

What do we want from a representation?

- **Rich enough** to express all of the knowledge necessary for solving the task
- As **close to the problem** as possible: Compact, natural, maintainable, transparent
- **Tractable**: Amenable to efficient computation
- **Learnable**: Should be able to acquire new knowledge from data, past experiences, people
- Able to **trade off** accuracy and computation time

Primary Dimensions

We will classify domains by three main dimensions:

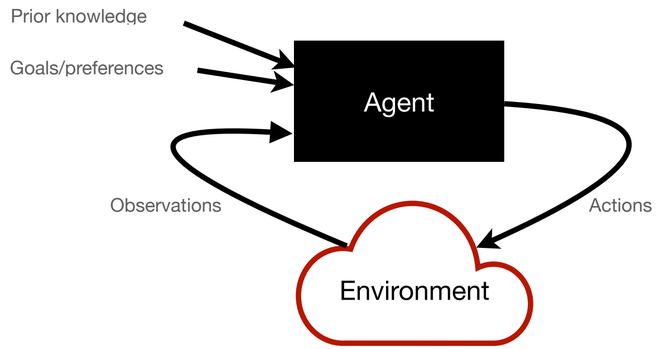
1. **Uncertainty:** deterministic vs. stochastic settings
2. **Interaction:** Online vs. offline interaction
3. **Number of agents:** Single vs. multiple agents

1. Uncertainty

Multiple aspects of an environment may be **deterministic** (no randomness) or **stochastic** (some randomness)

1. Observations and state ("sensing uncertainty")
   - **Fully observable**: observations directly determine **state**
   - **Partially observable**: **many** possible states for same observations; or observations are **misleading**
2. Dynamics ("effect uncertainty")
   - **Deterministic dynamics**: state completely determined by action and prior state
   - **Stochastic dynamics**: probability distribution over possible states from an action

2. Interaction



When does the agent decide what to do?

- **Offline:** Agent determines what to do **before** interacting with the environment
- **Online:** Agent determines what to do **while** interacting with the environment
  - Often more computationally demanding
  - Requires timely answers

3. Number of Agents

Does the agent (need to) explicitly consider other agents?

- **Single agent:**
  - No other agents in the environment, or
  - Behaviour of other agents is fixed (part of **nature**)
- **Multiple Agents:**
  - Other agents in the environment, with **distinct** goals/preferences
  - Must **reason** about other agent's behaviour **and reasoning**
  - **Other agents' actions** affect agents goals/preferences, **and vice versa**

Other Dimensions

- Static vs. sequential action
- Goals vs. complex preferences
- Episodic vs. continuing
- State representation scheme
- Perfect vs. bounded rationality

Different dimensions **interact**; you can't just set them arbitrarily

Static vs. Sequential Action

How many actions does the agent need to select?

- **Static:** the agent selects a **single** action
  - Classify an image
  - Diagnose a disease based on symptoms
  - Recommend a driving route
- **Sequential:** the agent needs to take a **sequence** of actions
  - Participate in an automated negotiation
  - Choose a series of tests to diagnose a patient
  - Navigate through an environment
- In a **deterministic** setting, this can be an arbitrary distinction

Goals vs. Preferences

How complicated a goal is the agent trying to achieve?

- **Goal:** A simple desired condition
  - **Maintenance goal:** Keep some already-true condition true in **all visited states**
  - **Achievement goal:** Condition should be true in **final state**
  - E.g.: Robot trying to deliver banana to Sam without hurting anyone or making a mess
- **Preferences:** Varying desirability of different outcomes, trade-offs
  - **Ordinal preferences:** Only the **ordering** of outcomes is important
  - **Cardinal preferences:** **Magnitude** of preference also matters

Knowledge Given vs. Knowledge Learned

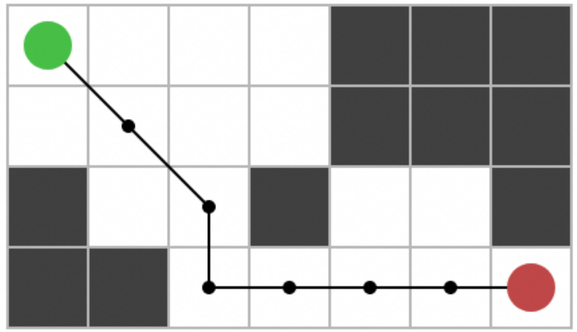
How much does the agent know about the world in advance?

- The agent **has a model** of the world **before** it acts
- The agent must **learn** how the world works
  - from **data**
  - from **experience**
  - often still starts with *some* **prior knowledge**

State Representation

How does the agent describe the world?

- **Enumerate** every possible state of the world
  - *Question:* How would you do this in **pathfinding**?
  - *Question:* How would you do this in **chess**?
- Factor each state into **features**
  - May or may not be **observable**
  - 20 binary features can represent over a million states
  - *Question:* **Pathfinding** features?
  - *Question:* **Chess** features?
- **Relationships** and **objects**



https://www.growingwiththeweb.com/2012/06/a-pathfinding-algorithm.html

Episodic vs. Continuing

Is the task ever **done**?

- **Episodic:** The agent eventually reaches a **final state**
- **Continuing:** The agent keeps acting **forever**
- Especially crucial distinction in reinforcement learning

Related: **Planning horizon**

Question: How would you classify

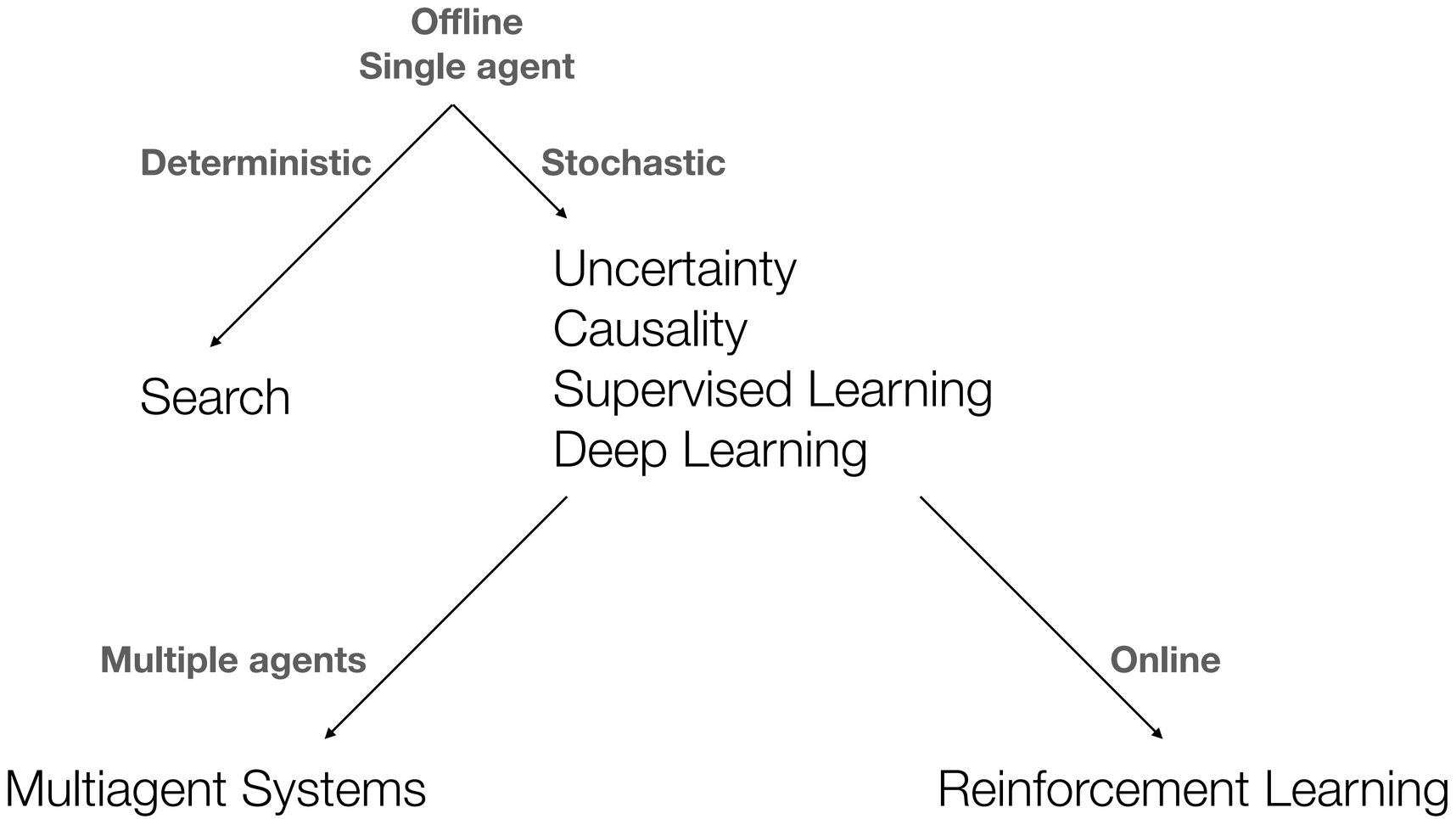
1. Pathfinding?
2. Chess?
3. Automated financial trading?

Perfect Rationality vs. Bounded Rationality

Is it feasible for the agent to achieve the **ideal optimum**, or must it trade off **solution quality** against **computational cost**?

- **Perfect rationality:** The agent can derive the best course of action without accounting for **computational limitations**.
- **Bounded rationality:** Agent decides on best action that **it can find** within its computational limitations
  - **Anytime algorithm:** Solution quality improves with time

Course Topics Breakdown



Summary

- Formal **representation** of an environment is essential for building agents
  - Many representations are possible for the same environment
  - Different representations are useful for different solutions
- We can usefully classify environments and representations according to a number of **dimensions**
  - Different properties call for different AI techniques