CPSC 322: Introduction to Artificial Intelligence
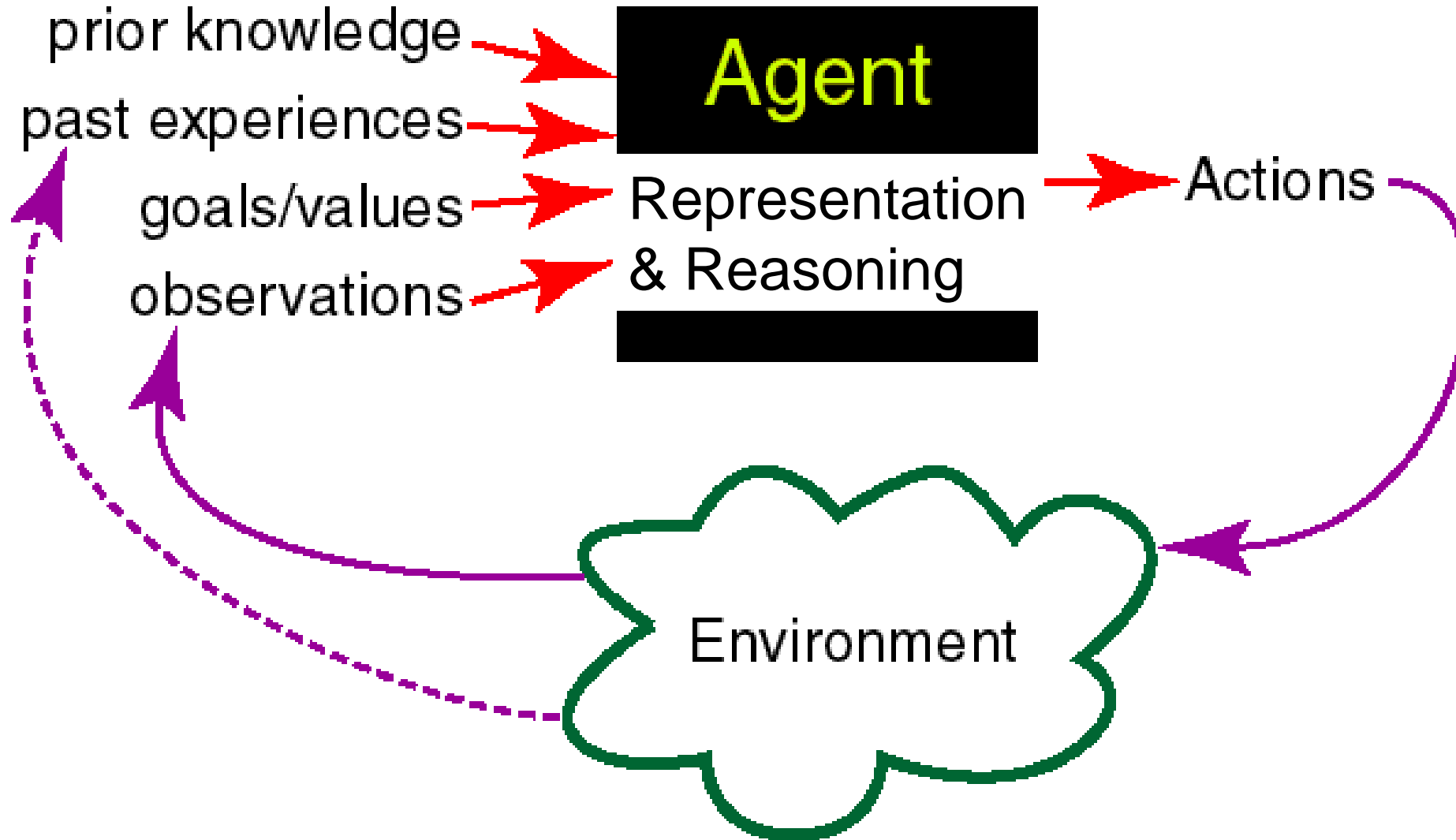## Lecture 03: Representational Dimensions

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Adapted from slides by Cristina Conati, Giuseppe Carenini, Varada Kolhatkar, and Jordon Johnson

Today's Class: Learning Goals

- Discuss different **representational dimensions** of problems in AI
- Assess the **size of the state space** of a given problem

Big Picture – CPSC 322

Problem		Environment	
		Deterministic	**Stochastic**
Static	Constraint Satisfaction	*Variables + Constraints* Search Arc Consistency Local Search	
	Query	*Logics* Search	*Bayesian (Belief) Networks* Variable Elimination
Sequential	Planning	*STRIPS* Search	*Decision Networks* Variable Elimination

Representation Reasoning Technique

What do we need to *represent*?

- The ***environment/world***
  - What different **configurations** (**states**/**possible worlds**) can the world be in, and how do we **denote** them?
  - *Chessboard, information about a patient, robot location*
- How the world ***works***
  - We will focus on…
    - *Constraints*: *can **only** write **one** exam at a time*
    - *Causal* relationships:
      *what are the **causes** and **effects** of brain disorders?*
    - Action *preconditions* and *effects*:
      ***when** can I press this button, and **what** happens if I do?*

Corresponding Reasoning *Tasks/Problems*

-- Static -- (vertical label, left margin)

-- Sequential -- (vertical label, left margin)

- **Constraint Satisfaction**
  - **Find a <u>state</u> that <u>satisfies</u> some set of <u>constraints</u>**
  - *What is a feasible schedule for final exams?*
- **Answering Queries**
  - **Is a given <u>proposition</u> true/likely, given what is known?**
  - *Does this patient suffer from chicken pox?*
- **Planning**
  - **Choose <u>actions</u> to reach a <u>goal</u> state or maximize utility**
  - *Navigate a maze while collecting gems and avoiding monsters*

Representation and Reasoning *System*

- A (**representation**) **language** in which
the **environment** and how it **works** can be **described**

- Computational (**reasoning**) **procedures** to compute a **solution** *(e.g., an answer, a sequence of actions)* to a problem in that environment

The **choice** of an appropriate **R&R system** depends in part on a **key property** of the **environment** and of the **agent's knowledge**

Deterministic vs. Stochastic (Uncertain) Domains

- **Sensing Uncertainty**
  - Can the agent fully observe the current state of "the world"?

- **Effect Uncertainty**
  - Does the agent know for sure what the direct effects of its actions are?

- The environment is considered **deterministic** if the answer to both of these is **"yes"**, and **stochastic** otherwise

Chess

Factory Floor

Poker

Medical Diagnosis/Treatment

Deterministic vs. Stochastic Domains

- **Sensing Uncertainty**
  - Can the agent fully observe the current state of "the world"?
- **Effect Uncertainty**
  - Does the agent know for sure what the direct effects of its actions are?
- **Stochastic** if answer to either is "no"

Which statement is correct under these definitions?
A. Poker and chess are both stochastic
B. Chess is stochastic and Poker is deterministic
C. Poker and chess are both deterministic
D. Chess is deterministic and Poker is stochastic
E. Quit trying to make me think about stuff

Deterministic vs. Stochastic Domains

Historically, AI was divided into two camps:

- those who prefer representations based on **logic**
- those who prefer representations based on **probability**

Some years ago, **CPSC 322** covered **logic**, while **CPSC 422** introduced **probability**

- Now we introduce both kinds of representations in 322, and 422 goes into more depth

Some of the most exciting current research in AI involves **building bridges** between these camps

Dimensions of Representational Complexity

We've already discussed:

- **Static** (constraints, query) vs. **sequential** (planning)
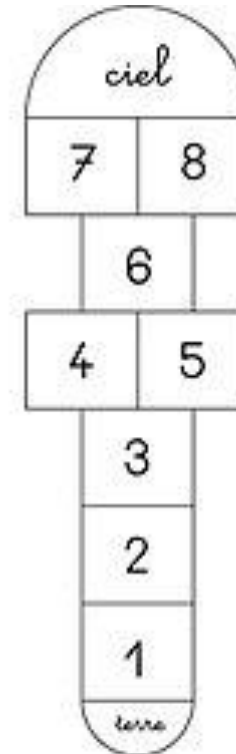- **Deterministic** vs. **stochastic** domains

Some other important dimensions of complexity:

- Explicit states, features/propositions, or relations
- Flat or hierarchical
- Knowledge given vs. knowledge learned from experience
- Goals vs. (complex) preferences
- Single-agent vs. multi-agent

Explicit States, Features/Propositions, or Relations

What are some ways we can model the environment?

- Explicitly enumerate the **states** of the world

- E.g.,
  - It works for hopscotch game
  - It will not work for chess!

Source: Wikipedia

Explicit States, Features/Propositions, or Relations

What are some ways we can model the environment?

- A state can be described in terms of **features**
  - Often a natural approach
  - 30 binary features (propositions, variables) can represent
    - $2^{30} > 1,000,000,000$ states

- Mars Explorer Example
  - {Weather, Temperature, LocX, LocY}
  - How many states?
  - {windy, not_windy}, [-100, -20], [0, 359], [-90, 90]
  - Num of states = 2 x 81 x 360 x 181

Explicit States, Features/Propositions, or Relations

What are some ways we can model the environment?

- States can be described in terms of **objects** and **relationships**
- There is a feature/proposition for each relationship on each possible tuple of individuals

- University Example
  - Registered(S,C) = {T,F} ← relationship
  - Students = {s1, s2, s3, s4} ← individuals/objects
  - Courses = {c1, c2, c3} ← individuals/objects
  - E.g., Registered(s2, c1)
  - Number of propositions: $4 \times 3 = 12$
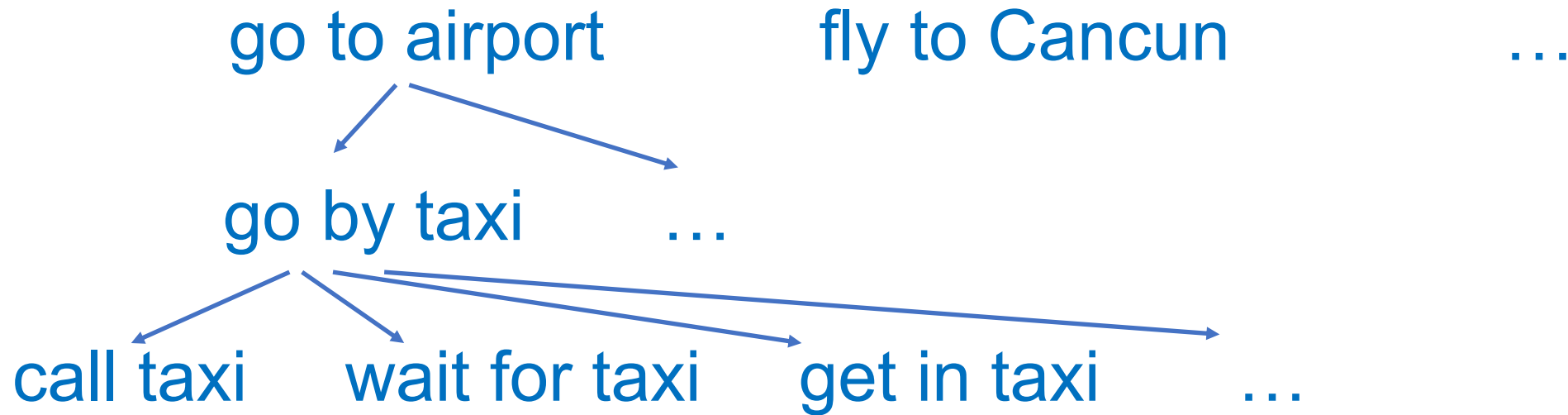 - Number of possible states: 2^{12}

Suppose we have one binary relation – Likes(x,y) – and 9 individuals. How many states?

A. 81^2

B. 2^9

C. 2^{81}

D. 10^9

E. 42

Flat vs. Hierarchical

Is it useful to model the entire world at the same level of abstraction?

- One level of abstraction: **flat**
- Multiple levels of abstraction: **hierarchical**

- **Example:** Planning a trip to a resort in Cancun, Mexico

go to airport   fly to Cancun   …

go by taxi   …

call taxi   wait for taxi   get in taxi   …

Knowledge Given vs. Knowledge Learned

How does the agent obtain information?

- The agent is **provided** with a model of the world **once and for all**

      OR

- The agent can **learn** about the world through **experience**
    - Even in such cases, the agent **still** starts out with some amount of **prior knowledge**

Goals vs. (Complex) Preferences

An agent may have a **goal** that it wants to achieve
- Some **state** (or set of states) of the world that the agent **wants** to **be in**
- Some **proposition** (or set of propositions) that the agent **wants** to **make true**

An agent may have **preferences**
- There is some **preference/utility function** that describes how **"happy"** the agent is in each state of the world
    - the **task** is to reach a state where the agent is **as happy as possible**

Preferences can be **complex**…
- I want the latest Dungeons & Dragons expansion book
- I want it as soon as possible
- I don't want to expend effort
- If I order online, I have to wait for delivery
- If I go pick it up now at the local games store, I'll have to leave the house

Single Agent vs. Multi-agent domains

Does the environment include other agents?

- If there are other agents whose actions affect us, it can be useful to **explicitly model their goals and beliefs** rather than considering them as part of the environment

- Other agents can be
  - **cooperative**
  - **competitive**
  - **a bit of both**

Dimensions of Representational Complexity in 322

- **Static** (constraints, query) and **sequential** (planning) reasoning tasks
- **Deterministic** and **stochastic** domains

- Explicit states, features/propositions, or relations
- Flat or hierarchical
- Knowledge given vs. knowledge learned from experience
- Goals vs. (complex) preferences
- Single-agent vs. multi-agent

not in this course