Lecture 2

Representational Dimensions

ANNOUNCEMENT

- Assignment 0 due on Wednesday
- You can send it via email by 4:30 on Wednesday. if you want it to count, in case you get into the course

Today's Lecture

- Recap from last lecture
- Representation and Reasoning: Dimensions

- An Overview of This Course
- Further Representational Dimensions
- Intro to search (time permitting)

Course Essentials

- Textbook: Artificial Intelligence: Foundations of Computational Agents. by Poole and Mackworth. (P&M)
- We will cover at least Chapters: 1, 3, 4, 5, 6, 8, 9
- Connect for assignments and marks
- Piazza for Discussion board
- AIspace: online tools for learning Artificial Intelligence http://aispace.org/

What is Artificial Intelligence?

Question: We use the following definition

- The study and design of

A. Systems that think rationally

B. Systems that act like humans

C. Systems that act rationally

D. Systems that think like humans

What is Artificial Intelligence?

Clicker Question: We use the following definition

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A. Systems that think rationally

B. Systems that act like humans

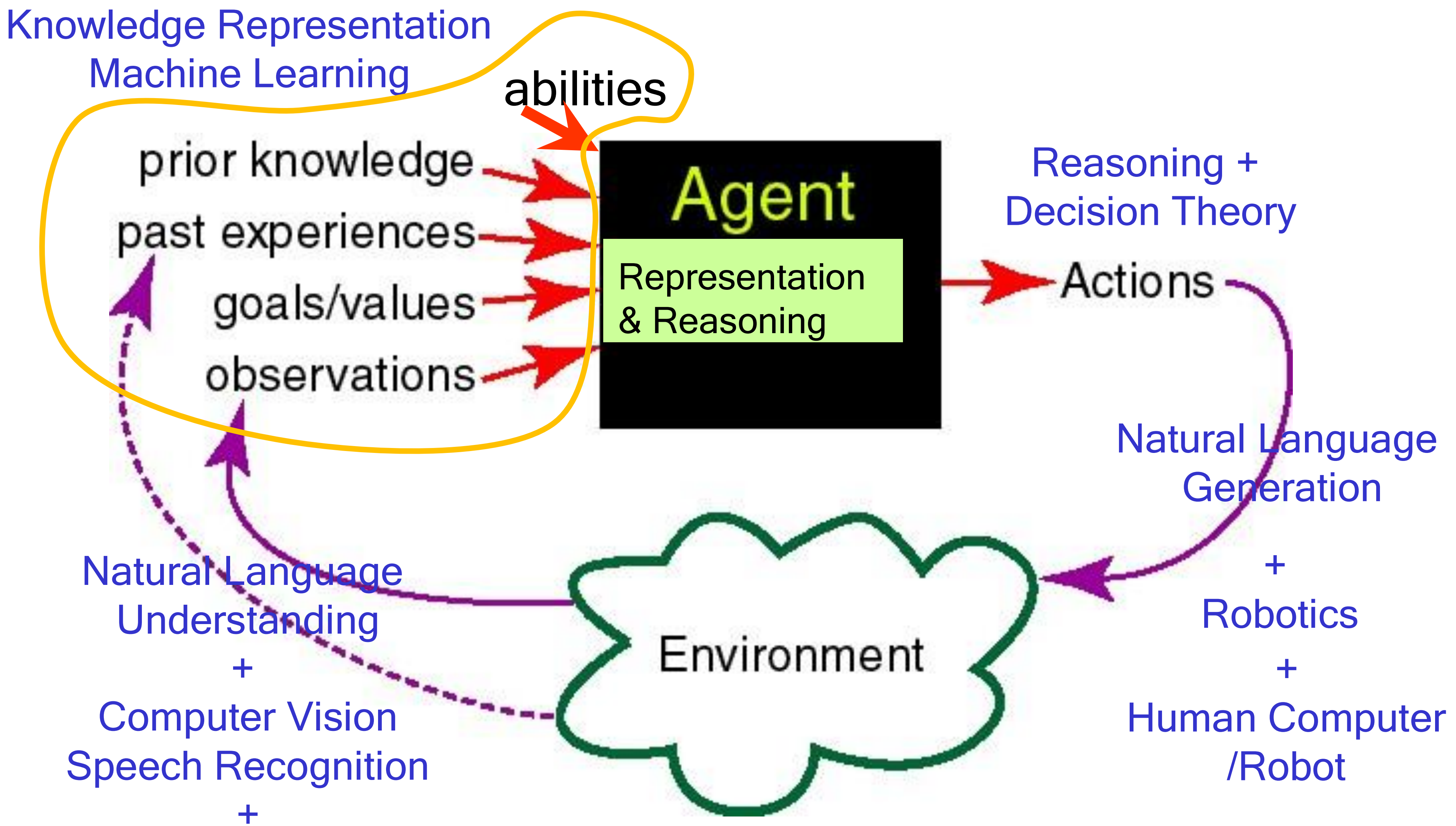
[✓ C. Systems that act rationally]

D. Systems that think like humans

AI as Study and Design of Intelligent Agents

- Intelligent agents: artifacts that act rationally in their environment
- Their actions are appropriate for their goals and circumstances
- They are flexible to changing environments and goals
- They learn from experience
- They make appropriate choices given perceptual limitations and limited resources
- This definition drops the constraint of cognitive plausibility

- Same as building flying machines by understanding general principles of flying (aerodynamic) vs. by reproducing how birds fly



Knowledge Representation
Machine Learning

abilities

prior knowledge

past experiences

goals/values

observations

Agent

Representation
& Reasoning

Reasoning +
Decision Theory

Actions

Natural Language
Generation

+

Robotics

+

Human Computer
/Robot

Environment

Natural Language
Understanding

+

Computer Vision
Speech Recognition

+

Intelligent Agents in the World

Interaction

Physiological Sensing

Mining of Interaction Logs

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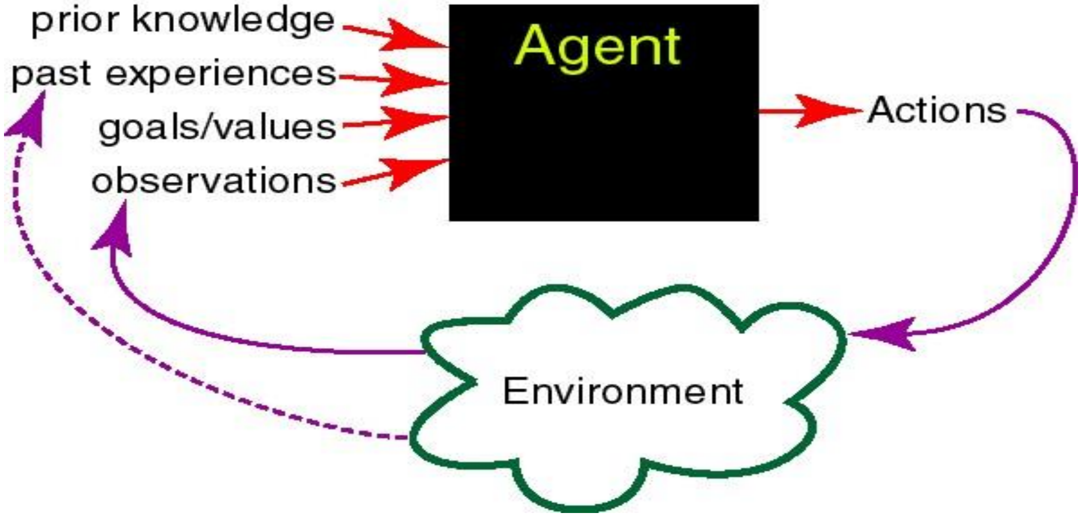

Representation and Reasoning

Representation
& Reasoning

To use these inputs an agent needs to representthem

□ knowledge

One of AI goals: specify how a system can

- Acquire and represent knowledge about a domain (representation)
- Use the knowledge to solve problems in that domain (reasoning)

Representation and Reasoning (R&R) System

- A representation language to describe
- The environment

- Problems (questions/tasks) to be solved
- Computational reasoning procedures to compute a solution to a problem
- E.g., an answer, sequence of actions problem ⟹ representation ⟹ computation⟹ representation ⟹ solution
- Choice of an appropriate R&R system depends on various dimensions, e.g. properties of
- the environment, the type of problems, the agent, the computational resources, etc.

Representational Dimensions

Environment

Deterministic Stochastic

Problem Type

Static

We'll start by describing dimensions related to the problem and environment

Each cell will include a R&R system covered in the course

Sequential

Then we'll include in each
cell the various R&R Then
we'll include in systems
covered in the each cell
R&R system
course, and discuss some covered in the course
more dimensions

Problem Types

- Static: finding a solution does not involve reasoning into the future (time is ignored)
- One-step solution

- Sequential: finding a solution requires looking for a number of steps into the future, e.g.,
- Fixed horizon (fixed number of steps)
- Indefinite horizon (finite, but unknown number of steps)

Problem Types

- Constraint Satisfaction - Find state that satisfies set of constraints (static).
- e.g., what is a feasible schedule for final exams?
- Answering Query - Is a given proposition true/likely given what is known? (static).
- e.g., does the patient suffers from viral hepatitis?

- Planning - Find sequence of actions to reach a goal state / maximize outcome (sequential).
- e.g., Navigate through an environment to reach a particular location

Deterministic vs. Stochastic (Uncertain) Environment
Representational Dimensions

Problem Type		Environment	
		Deterministic	Stochastic
Static	Constraint Satisfaction		
	Query		
Sequential	Planning		

Deterministic vs. Stochastic (Uncertain) Environment

- Sensing Uncertainty: The agent cannot fully observe the current state of the world when acting

	Sensing Uncertainty?
Teacher's explanation	
Soccer Player Kick	

- Effect Uncertainty: the agent does not know for sure the immediateeffects of its actions

Deterministic vs. Stochastic (Uncertain) Environment

- Sensing Uncertainty: The agent cannot fully observe the current state of the world

	Sensing Uncertainty?
Teacher’s explanation	YES
Soccer Player Kick	NO

- Effect Uncertainty: the agent does not know for sure the effects of its actions

Deterministic vs. Stochastic (Uncertain) Environment

	Effect Uncertainty?
Teacher’s explanation	
Soccer Player Kick	

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	Sensing Uncertainty?
Teacher’s explanation	YES
Soccer Player Kick	NO

- Effect Uncertainty: the agent does not know for sure the effects of its actions

	Effect Uncertainty?
Teacher’s explanation	YES
Soccer Player Kick	YES

Question: Chess and Poker

An environment is stochastic if at least one of these is true

- Sensing Uncertainty: the agent cannot fully observe the current state of the world

Deterministic vs. Stochastic (Uncertain) Environment

- Effect Uncertainty: the agent does not know for sure the immediate, direct effects of its actions

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

Question: Chess and Poker

An environment is stochastic if at least one of these is true

- Sensing Uncertainty: the agent cannot fully observe the current state of the world
- Effect Uncertainty: the agent does not know for sure the immediate, direct effects of its actions

A. Poker and Chess are both stochastic

B. Chess is stochastic and Poker is deterministic

C. Poker and Chess are both stochastic

D. Chess is deterministic and Poker is stochastic

Deterministic vs. Stochastic Domains

- Historically, AI has been divided into two camps: those who prefer representations based on logic and those who prefer probability.

Note: Some of the most exciting current research in AI is actually building bridges between these camps.

Representational Dimensions

Environment

Deterministic Stochastic

Problem Type

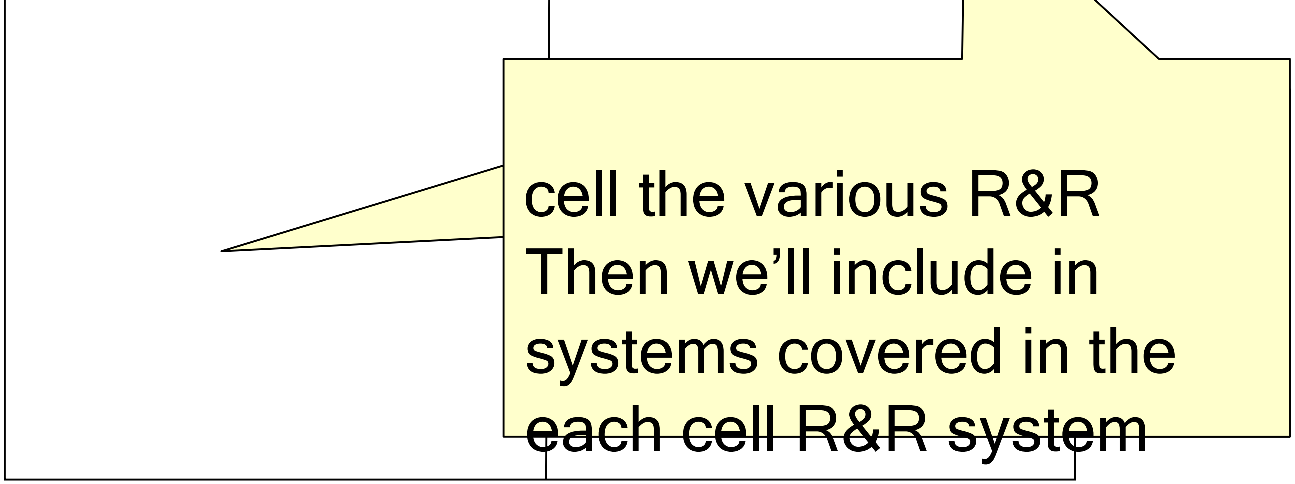
We described Each cell will

Static dimensions include a R&R

related to the system covered

problem and in the course environment

Sequential Now we include in each



cell the various R&R
Then we'll include in
systems covered in the
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course, and discuss some covered in the course
more dimensions

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Representation

Reasoning Technique

		Environment	
Problem Type		Deterministic	Stochastic
Static	Constraint Satisfaction	Arc Consistency Variables + Constraints Search	
	Query	Logics Search	Bayesian Nets Variable Elimination
Sequential	Planning	STRIPS Search	Decision Nets Variable Elimination Markov Processes Value Iteration

Repre

Other Representational Dimensions

We've already discussed:

- Problem Types (Static vs. Sequential)
- Deterministic versus stochastic domains

Some other important dimensions

- Representation scheme: Explicit state or features or relations
- Flat or hierarchical representation
- Knowledge given versus knowledge learned from experience
- Goals versus complex preferences

- Single-agent vs. multi-agent

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Explicit State vs Features

How do we model the environment?

- You can enumerate the states of the world or
- A state can be described in terms of features
- Often a more natural description
- 30 binary features (also called propositions) can represent

How do we model the environment?

Explicit State vs Features

- You can enumerate the states of the world or
- A state can be described in terms of features
- Often a more natural description
- 30 binary features (also called propositions) can represent

2^{30}=1,073,741,824 states

Mars Explorer Example

Weather {S, C}

Explicit State vs Features

Temperature [-40, 40]

Longitude

[0, 359] [0, 179]

Latitude

One possible state

Number of possible states (mutually exclusive)

Mars Explorer Example

Explicit State vs Features

Weather {S, C}

Temperature [-40, 40]

Longitude

[0, 359] [0, 179]

Latitude

One possible state {S, -30, 320, 210}

Number of possible states (mutually exclusive)

2 x 81 x 360 x 180

Explicit State vs. Features vs. Relations

- States can be described in terms of objects and relationships
- There is a proposition for each relationship on each tuple of objects
- University Example:
- Students (S) = {s1, s2, s3, …, s200)
- Courses (C) = {c1, c2, c3, …, c10}
- Registered (S, C)
- Number of Relations:

- Number of Propositions:

- Number of States:

Explicit State vs. Features vs. Relations

- States can be described in terms of objects and relationships
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- University Example:
- Students (S) = {s1, s2, s3, …, s200)

- Courses (C) = {c1, c2, c3, …, c10}
- Registered (S, C)

- Number of Relations: 1
- Number of Propositions:

200*10

33

- Number of States:

2^{2000}

Question

One binary relation (e.g., likes) and 9 individuals (e.g. people). How many states?

A. 81^2

B. 2^{18}

C. 2^{81}

D. 10^9

Question

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Flat vs. hierarchical

- Should we model the whole world on the same level of abstraction?
- Single level of abstraction: flat
- Multiple levels of abstraction: hierarchical

- Example: Planning a trip from here to a resort in Cancun

Going to the airport

Take a cab

Call a cab

Lookup number

Dial number

Ride in the cab

Pay for the cab

Check in ....

- This course: mainly flat representations
- Hierarchical representations required for scaling up.

Knowledge given vs. knowledge learned from experience

- The agent is provided with a model of the world once and for all or
- The agent can learn how the world works based on experience

- in this case, the agent often still needs some prior knowledge

- This course: mostly knowledge given
- Learning: CPSC 340 and CPSC 422

Goals vs. (complex) preferences

- An agent may have a goal that it wants to achieve, e.g.,
- there is some state or set of states that the agent wants to be in
- there is some proposition or set of propositions that the agent wants to make true
- An agent may have preferences

- a preference/utility function describes how happy the agent is in each state of the world
- Agent's task is to reach a state which makes it as happy as possible
- Preferences can be complex

What beverage to order?

- I am in a hurry so I need something quickly
- I like Cappuccino better than Espresso, but it takes longer to make…

- This course: goals and simple preferences

Single-agent vs. Multi-agent domains

- Does the environment include other agents?

- If there are other agents, it can be useful to explicitly model
- their goals and beliefs,
- how they react to our actions
- Other agents can be: cooperative, competitive, or a bit of both

- This course: only single agent scenario

Summary

Would like most general agents possible, but in this course we need to restrict ourselves to:

- Flat representations (vs. hierarchical)
- Knowledge given (vs. knowledge learned)

- Goals and simple preferences (vs. complex preferences)
- Single-agent scenarios (vs. multi-agent scenarios)

We will look at

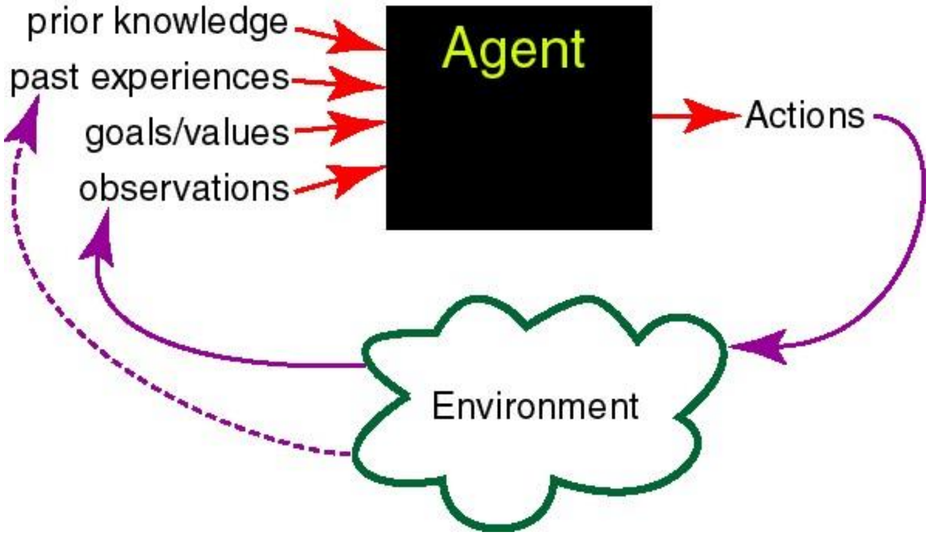
- Deterministic and stochastic domains
- Static and Sequential problems

And see examples of representations using

- Explicit state or features or relations

AI Application

- At the beginning of next class, we will look at some AI applications that you have found for your assignment 0



- You are asked to described them in terms of the elements above and some more
- What does the AI application do
- Goals

- prior knowledge needed
- past experiences that it does (or could) learn from
- Observations needed
- Actions performed
- AI technologies used
- Why is it intelligent?
- Evaluation?

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Representational Dimensions

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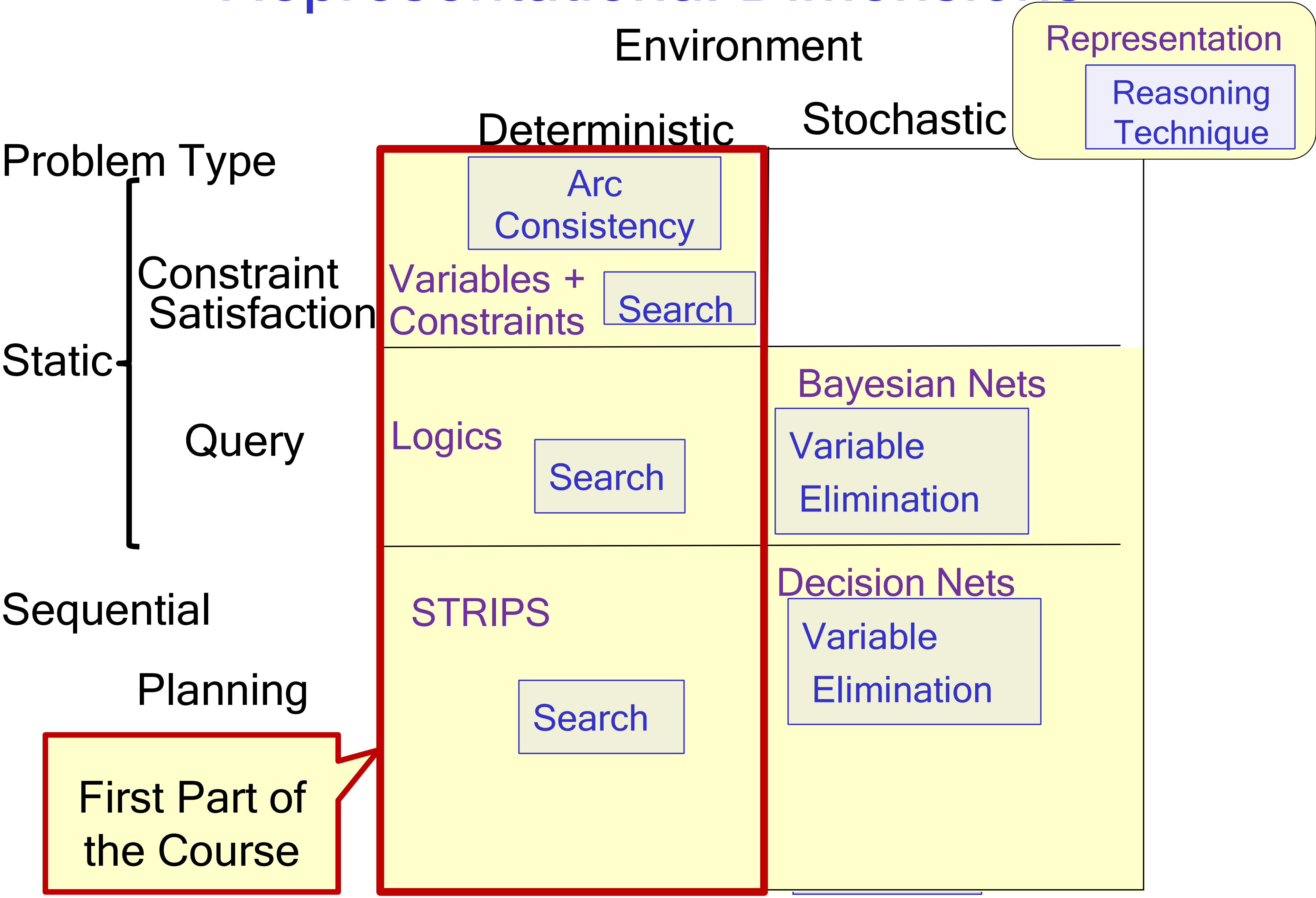
Representational Dimensions



Environment

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Representation

Reasoning Technique

First Part of the Course

Representational Dimensions

Environment

Problem Type		Deterministic	Stochastic
Static	Constraint Satisfaction	Arc Consistency Variables + Constraints Search	
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Representation

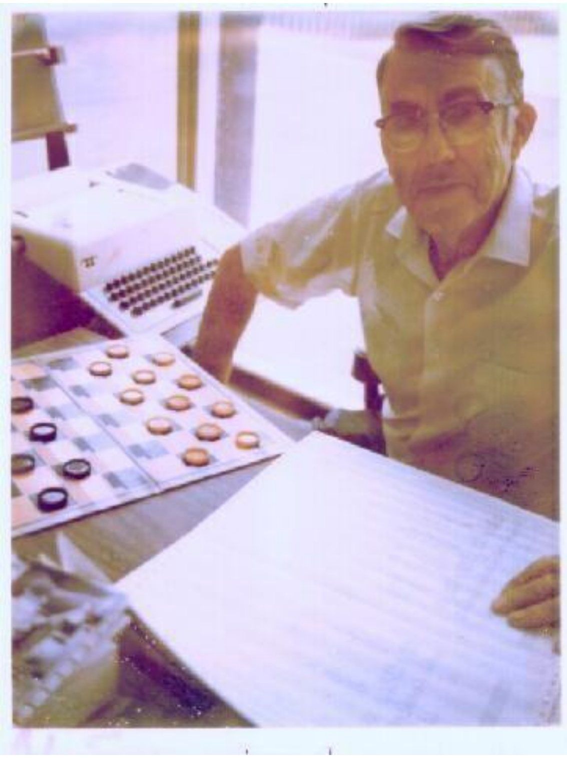
Reasoning Technique

We'll focus on Search

(Adversarial) Search: Checkers

- Early learning work in 1950s by Arthur Samuel at IBM
- Chinook program by Jonathan Schaeffer (UofA)
- Search explores the space of possible moves and their

  consequence



Source: *IBM Research*

- ✓ 1994: world champion
- ✓ 2007: declared unbeatable

(Adversarial) Search: Chess

In 1997, Gary Kasparov, the chess grandmaster and reigning world champion played against Deep Blue, a program written by researchers at IBM

Source: *IBM Research*

Slide

(Adversarial) Search: Chess

- Deep Blue's won 3 games, lost 2, tied 1

May 11th, 1997

Computer won world champion of chess

(Deep Blue) (Garry Kasparov)

(Reuters = Kyodo News)

- 30 CPUs + 480 chess processors
- Searched 126 million states per sec
- Generated 30 billion positions per move reaching depth 14 routinely

Search

- Often we are not given an algorithm to solve a problem, but only a specification of what a solution is ⇩

we have to search for a solution.

- Enumerate a set of potential partial solutions
- Check to see if they are solutions or could lead to one

Simple Search Agent

Deterministic, goal-driven agent

- Agent is in a start state
- Agent is given a goal (subset of possible states)
- Environment changes only when the agent acts
- Agent perfectly knows:
- actions that can be applied in any given state
- the state it is going to end up in when an action is applied in a given state

- The sequence of actions (and appropriate ordering) taking the agent from the start state to a goal state is the solution

Definition of a search problem

- Initial state(s)

- Set of actions (operators) available to the agent
- An action function that, given a state and an action, returns a new state
- Goal state(s)

- Search space: set of states that will be searched for a path from initial state to goal, given the available actions
- states are nodes and actions are links between them.

- Not necessarily given explicitly (state space might be infinite)
- Path Cost (we ignore this for now)

Three examples

1. The delivery robot planning the route it will take in a building to get from one room to another (Ch 1.6)

2. Vacuum cleaner world

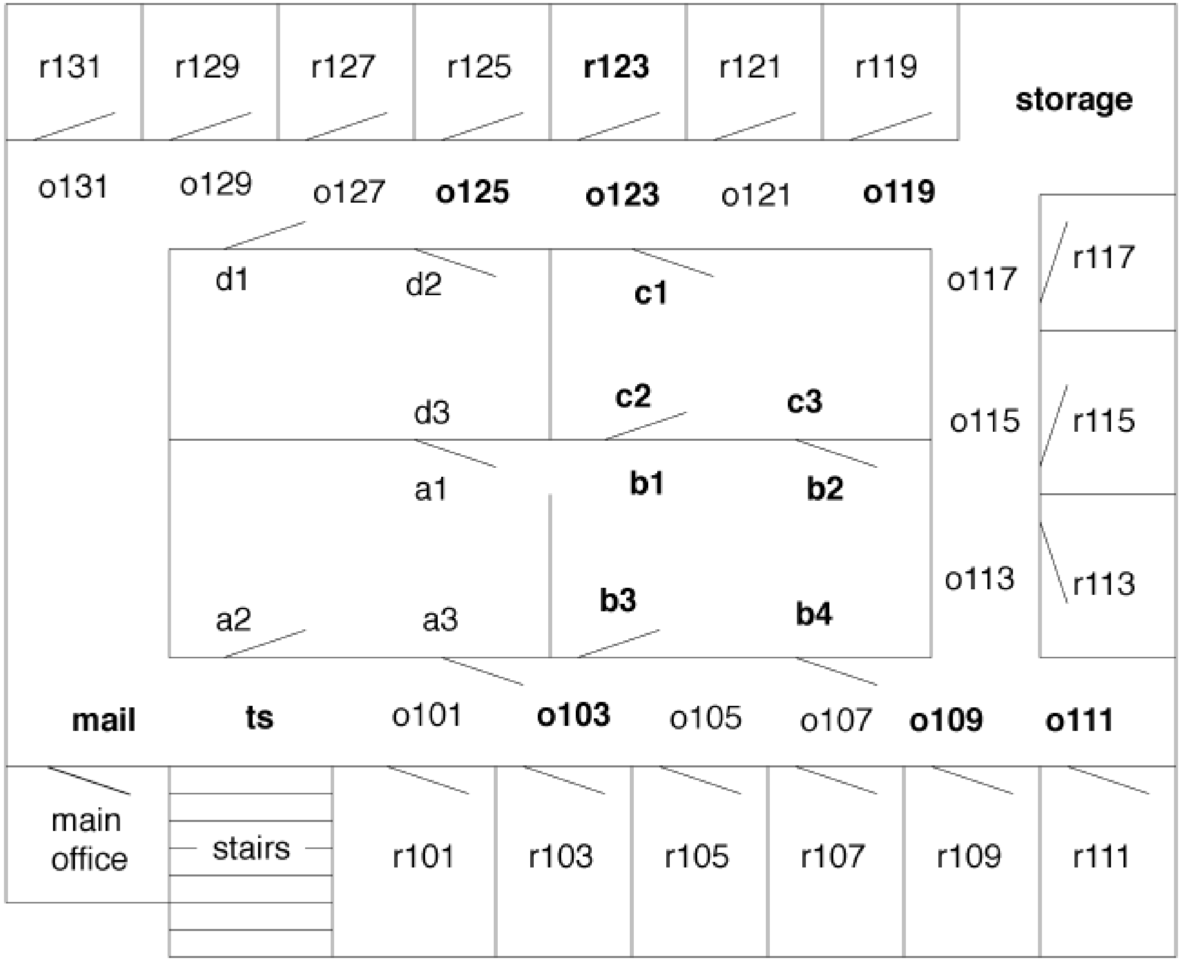
3. Solving an 8-puzzle

Slide

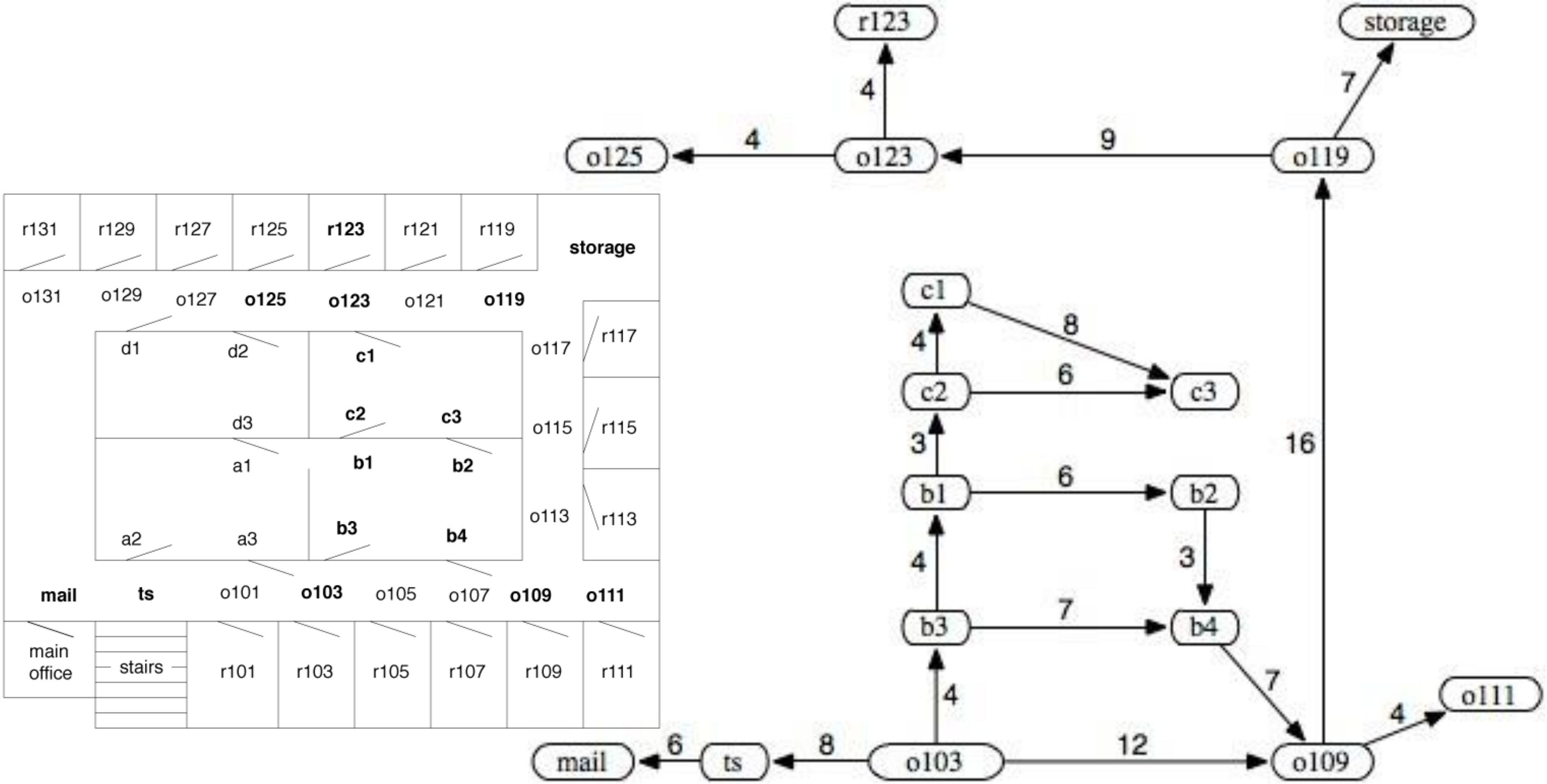
Environment for Delivery Robot (ch.1.6)

Simplified

- Consider only bold locations here
- Limits in direction of movement (e.g., can only move in the direction a door opens, can't go back to previous location, etc.)
- Start: o103
- Goal: r123



Search Space for the Delivery Robot



Learning Goals for today's class

- Define what is a representation and reasoning system
- Differentiate between single/static and sequential problems, as well as between deterministic and stochastic ones

TO DO for next class

•Read Ch 3 (3.1-3.5.2, 3.7.3)

•Assignment 0

•Review the definitions in the next three slides. I won't go over them next week

Graphs

- A directed graph consists of a set N of nodes (vertices) and a set A of ordered pairs of nodes, called edges (arcs).

- Node n_2 is a neighbor of n_1 if there is an arc from n_1 to n_2. That is, if □ n_1, n_2 □ □ A.

- A path is a sequence of nodes n_0, n_1,.., nk such that □ n_{i-1}, n_i □ □ A.
- A cycle is a non-empty path such that the start node is the same as the end node.
- A directed acyclic graph (DAG) is a graph with no cycles
- Given a set of start nodes and goal nodes, a solution is a path from a start node to a goal node

Graph specification for the Delivery Robot

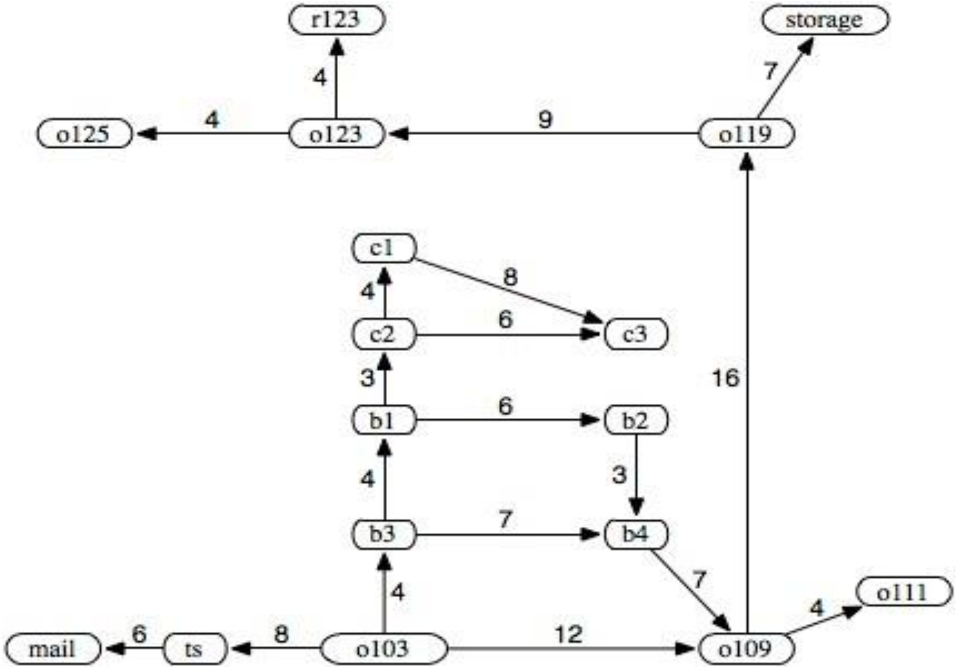
N={mail, ts, o103, b3, o109,...}

A={

⟨ts,mail⟩,

⟨o103,ts⟩, ⟨o103,b3⟩, ⟨o103,o109⟩,

...}



One of several solution paths:

⟨o103, o109, o119, o123, r123⟩

Branching Factor

- The forward branching factor of a node is the number of arcs going out of the node

- The backward branching factor of a node is the number of arcs going into the node

- If the forward branching factor of a node is band the graph is a tree, how many nodes are n steps away from that node?