CPSC 322: Introduction to Artificial Intelligence

Representational Dimensions and AI Applications

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Hope you already have done this

- Read the course information page carefully.
  https://github.com/kvarada/CPSS-322_students/blob/master/README.md

- Register for **iClicker** on Canvas.

- Register for the class on **Piazza**.
  https://piazza.com/ubc.ca/winterterm12019/cpsc322w12019

- Submit **Assignment 0** on Canvas.

- Submit the "Get to know you survey" on Canvas.

Course essentials

- **Textbook**: Available online!
  - We will cover at least Chapters: 1, 3, 4, 5, 6, 8, 9
- **Piazza**: stores all course material and used as a discussion forum
- **Canvas**: used for assignment submission and grades
- **AIspace**
  - New version: https://aispace2.github.io/AISpace2/index.html

Recap from last time

State whether True or False

1. AI is about building smarter programs or creating computer software that are capable of intelligent behaviour.

2. We adopt the rationality approach because many humans are not intelligent.

Recap from last time

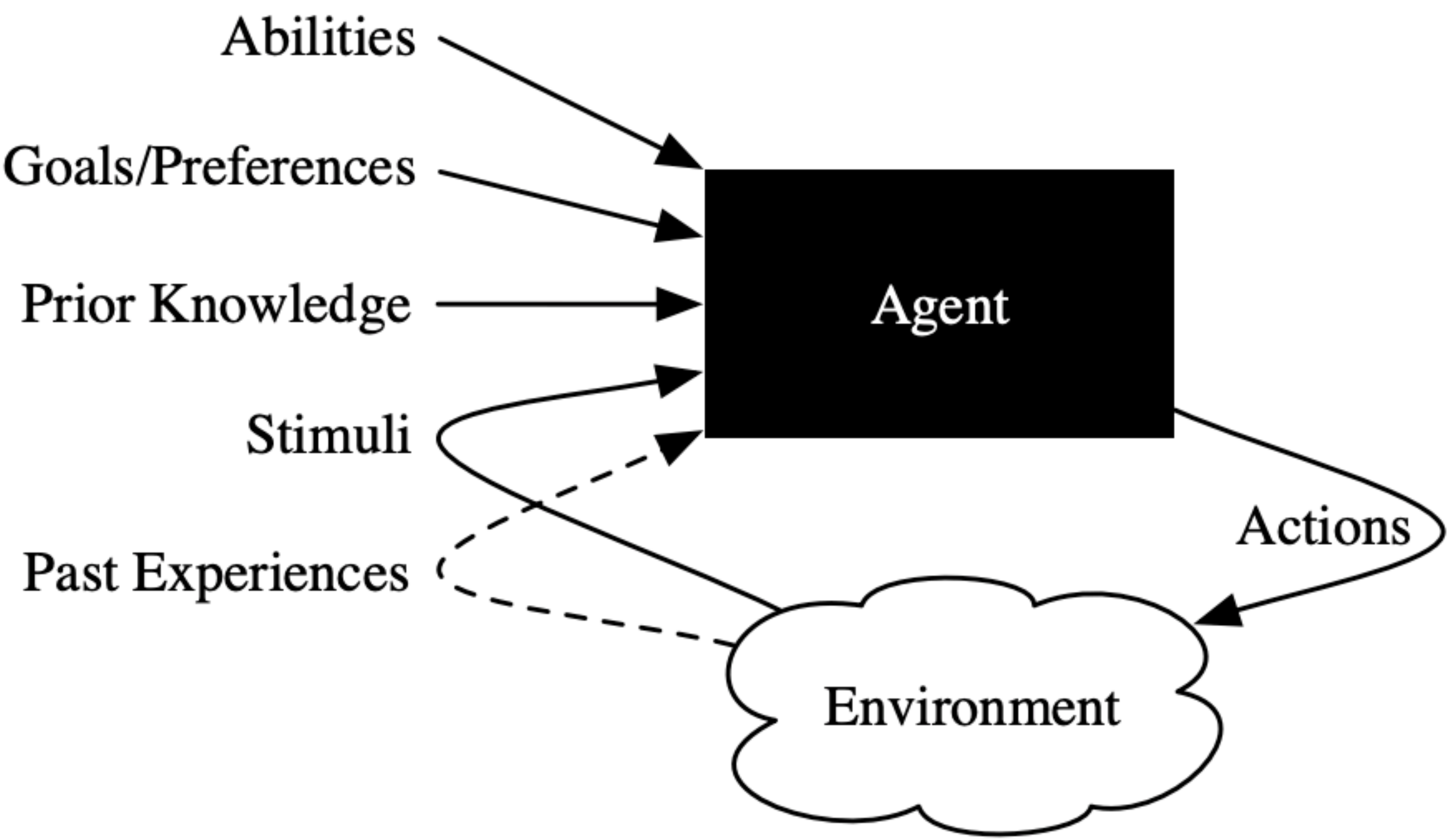
What among the following are examples of intelligent agents?

1. Humans

2. Assembly-line robot

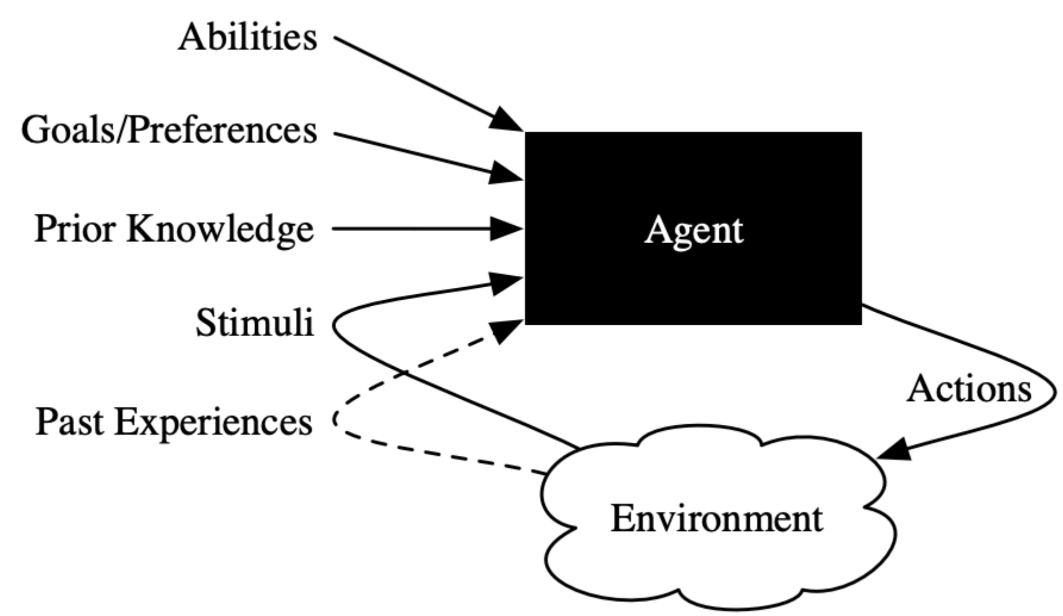
3. Driverless cars

Agents acting in an environment



Example agent: *thermostat for heater*

- abilities: turn heater on or off



- goals: conformable temperature, save fuel, save money
- prior knowledge: 24 hour cycle, weekends
- stimuli: temperature, set temperature, who is home, outside temperature
- past experiences: when people come and go, who likes what temperature

Questions?

Today's class: Learning outcomes

By the end of the class you will be able to

- discuss different representational dimensions (e.g., deterministic and stochastic)
- assess the size of the state space of a given problem
- discuss some AI applications

A rough CPSC 322 overview

Representation and reasoning

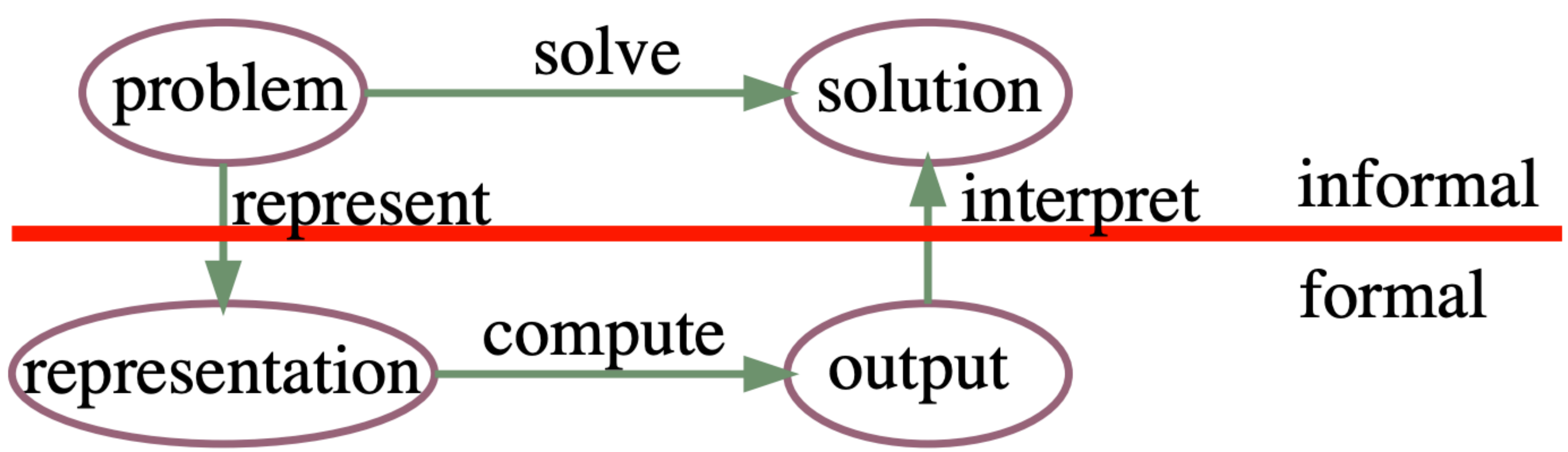
	Problem	Environment: Deterministic	Environment: Stochastic
Static	Constraint satisfaction	Variables + constraints Arc consistency Search	
Static	Query	Logics Search	Belief networks Variable elimination
Sequential	Planning	STRIPS Search	Decision networks Variable elimination Markov decision processes Value iteration

Representations and reasoning in solving problems

One of AI's goals is to specify how a system that can

- Representation: Acquire and represent knowledge about a domain

- Reasoning: Use the representation to solve problems in that domain



Example: IBM Watson

Uses knowledge from encyclopedias, dictionaries, thesauri, newswire, literary works, etc.

A Knowledge and Reasoning Toolkit for Cognitive Applications

The objective of the Knowledge and Reasoning Toolkit (KRT) is to bring content into a structured knowledge representation to integrate data from heterogeneous sources, and enable conversational access in support of humans engaging in conducting relevant tasks. Previously, extracting and representing such information from natural language, structured, and semi-structured (table) content is highly manual, tedious, and error prone. The KRT creates and leverages knowledge extraction, management, and reasoning techniques to reduce the human effort, ensure a principled representation, and support effective and fluent human-machine conversation.

ASIDE: Why does Watson think Toronto is a U.S. City?

Its largest airport is named for a world war II hero; its second largest for a world war II battle

Clue: U.S. cities

Watson's answer: What's Toronto???

Some discussion here:
http://www.cs.toronto.edu/~sheila/384/w11/why-toronto.pdf

Reasoning and representation system

A representation and reasoning system (RRS) consists of:

- A (representation) language in which the environment and how it works can be described.
- Computational (reasoning) procedures to compute a solution to a problem in that environment (i.e., an answer, a sequence of actions (plan))

The choice of an appropriate RRS depends on a key property of the environment and agent's knowledge.

We want the representation to be

- rich enough to express the knowledge to solve the problem
- as close to the problem as possible: compact, natural, maintainable
- amenable to efficient computation; able to express features of the problem we can exploit for computational gain
- learnable from data and past experiences
- able to trade off accuracy and computation time

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Representation and reasoning problems

Reasoning problems	Explanation	Example
Constraint satisfaction	Find state that satisfies a set of constraints	What is a feasible schedule for final exams?
Answering query	Is a given proposition TRUE or likely given what is known?	Does this patient suffer from chicken pox?
Planning	Find a sequence of actions to reach a goal state and/or maximize utility	Navigate through an environment to reach a particular location

What kind of problem?

Constraint satisfaction

Answering query

Planning

- Planning a vacation
- Does a patient have pneumonia?
- Finding the best path from a source to destination in a map
- Sudoku

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Static vs. sequential

How many actions does the agent need to perform?

Static

Single action

Examples

- Solve a Sudoku
- Diagnose a patient with a disease

Sequential

a sequence of actions

Examples

- Navigate through the environment to reach the goal state
- decide sequence of tests to enable a better diagnosis of the patient

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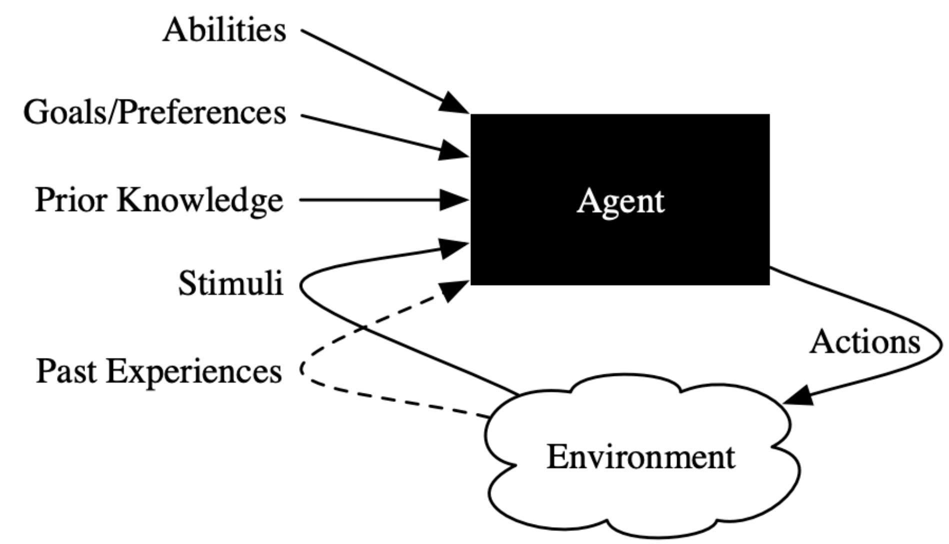
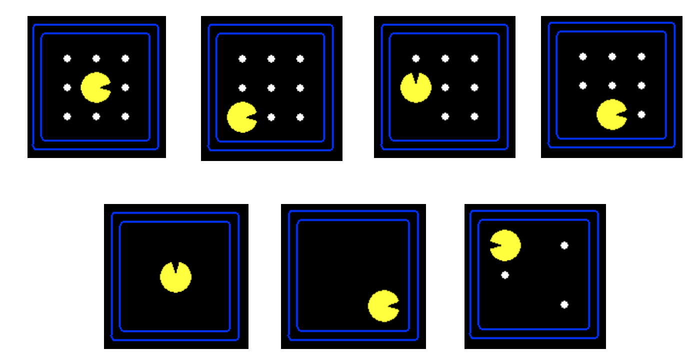
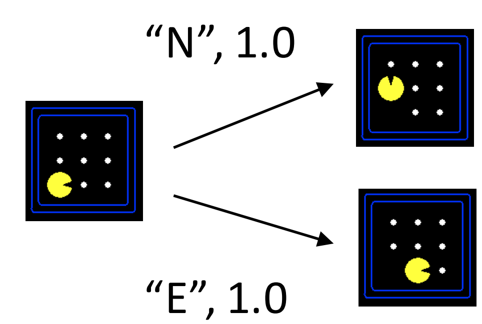
The environment or the world



What different configurations (i.e., states) can the world be in, and how do we denote them?



The environment enters a new state (different configuration) after each action of the agent.



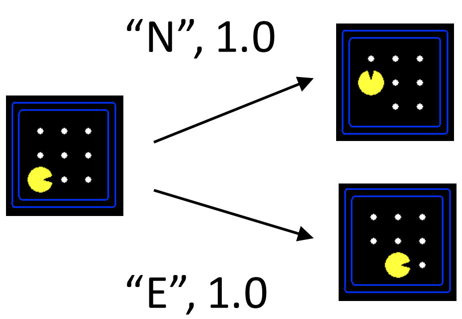
Credit: Pac-Man pictures from Berkeley AI course material

Deterministic vs. stochastic (uncertain)

If an agent knew the initial state and its action, could it predict the resulting state?

Deterministic

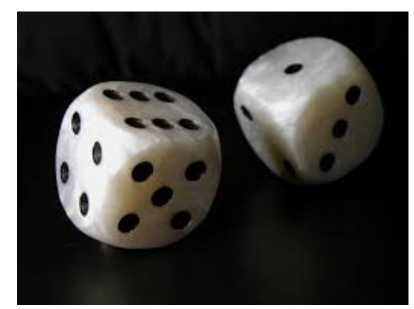
the resulting state is determined from the action and the current state



$$f(state_i, action_j) \rightarrow state_k$$

Stochastic

there is uncertainty about the resulting state



Dice games

Poker

Medical diagnosis

Deterministic vs. stochastic

Is the agent's knowledge certain or uncertain? Is the outcome of an action certain?

Stochastic if answer to any of the following is "No"

- Can the agent fully observe the current state of the world?
- Does the agent know for sure what the effects of its actions are?

Crossword puzzle

Medical diagnosis

Poker

Clicker question: Chess and Driverless car

Which of the following statements is True?

A. Chess is stochastic and Driverless car is deterministic.

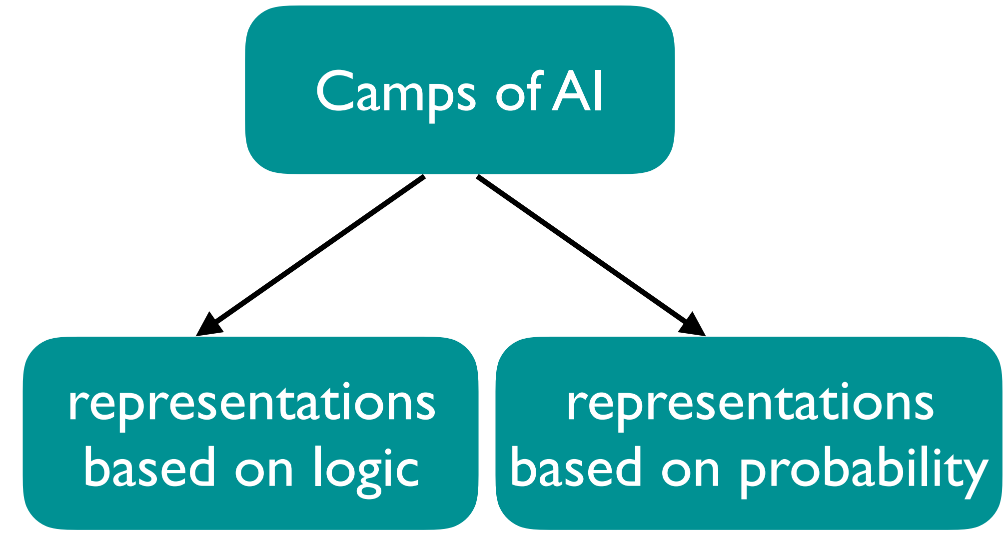
B. Chess is deterministic and Driverless car is stochastic.

C. Driverless car and Chess are both deterministic.

D. Chess and Driverless car are both stochastic.

Deterministic vs. stochastic

- Historically two camps of AI
- A few years ago, CPSC 322 covered logic, while CPSC 422 introduced probability.
- Now we introduce both representational families in 322, and 422 goes into more depth.
- So CPSC 322 should give you a better idea of what's included in AI.



Some of the most exciting current research in AI is actually bridging between these camps

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Other important dimensions

So far we've already discussed: Static (constraints, query) vs. sequential (planning) and deterministic vs. stochastic

Other important dimensions

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

Explicit states vs. features

- How do we model the environment?
- You can enumerate the possible states of the world.
- A state can be described in terms of features.
  - Often it is more natural to describe states in terms of assignments of values to features (variables).
  - 30 binary features (also called propositions) can represent $2^{30} = 1{,}073{,}741{,}824$ states.

Explicit states vs. features vs. relations

- 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*}
Students(S) = {*s1, s2, …, s100*}
Courses(C) = {*c1, c2, …, c10*}

relationship

objects

Example proposition
Registered(s4,c8)

Number of propositions = 1000
Number of states = 2^{1000}

Relations

One binary relation, likes(x,y), and 8 individuals (people). How many states?

A. 2^{64}

B. 10^{8}

C. 64^{2}

D. 64

Flat vs. hierarchical

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

<u>Flat</u>

You can model the world at one level of abstraction

<u>Hierarchical</u>

You can model the world at multiple levels of abstraction

Hierarchical examples:

- Planning a trip to a conference
- Delivery robot: Plan on levels of cities, districts, buildings.

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

Knowledge-given vs. knowledge-learned

How does the agent learn?

Knowledge-given
The agent is provided with a model of the world once and far all

Delivery robot:
Known maps,
probability of slipping

Knowledge-learned
The agent can learn how the world works based on experience. The agent usually start with some prior knowledge.

This course: *mostly* knowledge given.
Learning: CPSC 422 and CPSC 340

Goals vs. complex preferences

What does the agent want to achieve?

<u>Goals</u>

- An agent may have a goal that it wants to achieve
- There is some state or set of states of the world that the agent wants to be in
- There is some proposition or set of propositions that the agent wants to make true

<u>Complex preferences</u>

- 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

Where should I get raspberries?

- Closer the better.
- Farmers' market is better than a supermarket.
- Farmers' market is far.

This course: goals and simple preferences

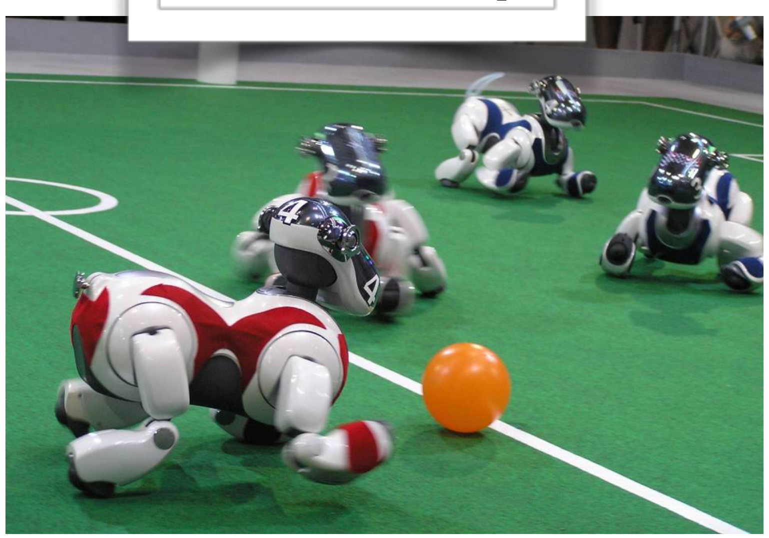
Single-agent vs. Multi-agent

Does the environment include other agents?

Single-agent

Only one agent in the environment

Robocup



Multi-agent

- Other agents whose actions affect us.
- Useful to explicitly model their goals and beliefs and how they react to our actions.
- Other agents can be cooperative, competitive or a bit of both.

This course: mostly single agents

Dimensions considered in CPSC 322

- Uncertainty
  - Deterministic vs. stochastic
- How many actions does the agent needs to perform?
  - Static vs. sequential
- Representation scheme
  - Explicit states vs. propositions vs. relations

Representational complexity in CPSC 322

- Reasoning tasks (constraint satisfaction, logic and probabilistic inference, planning)
- Deterministic vs. Stochastic domains
- Explicit state or features or relations
- Flat or hierarchical
- Knowledge given versus knowledge learned from experience
- Goals vs. (complex) preferences
- Single-agent vs. multi-agent

Not in CPSC 322

Course map

Dimen- sions / Course Modules	Deterministic vs. Stochastic	Static vs. Sequential	States vs. Features vs. Relations
1. Search	Deterministic	Static	States
2. CSPs	Deterministic	Static	Features
3. Planning	Deterministic	Sequential	States or Features
4. Logic	Deterministic	Static	Relations
5. Uncertainty	Stochastic	Static	Features
6. Decision Theory	Stochastic	Sequential	Features

Some AI applications

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Deep Blue

In In 1996 and 1997, Gary Kasparov, the world chess grandmaster played two tournaments against Deep Blue, a program written by researchers at IBM

Deep Blue

30 CPUs + 480 chess processors
Searched 126,000,000 nodes per sec
Generated 30 billion positions per move reaching depth 14 routinely

Deep Blue's Results in the first tournament:
- won 1 game,
- lost 3
- tied 1

Deep Blue's Results in the first tournament:
- won 3 games,
- lost 2
- tied 1

Sample A* applications

- An Efficient A* Search Algorithm For Statistical Machine Translation. 2001
- The Generalized A* Architecture. Journal of Artificial Intelligence Research (2007)

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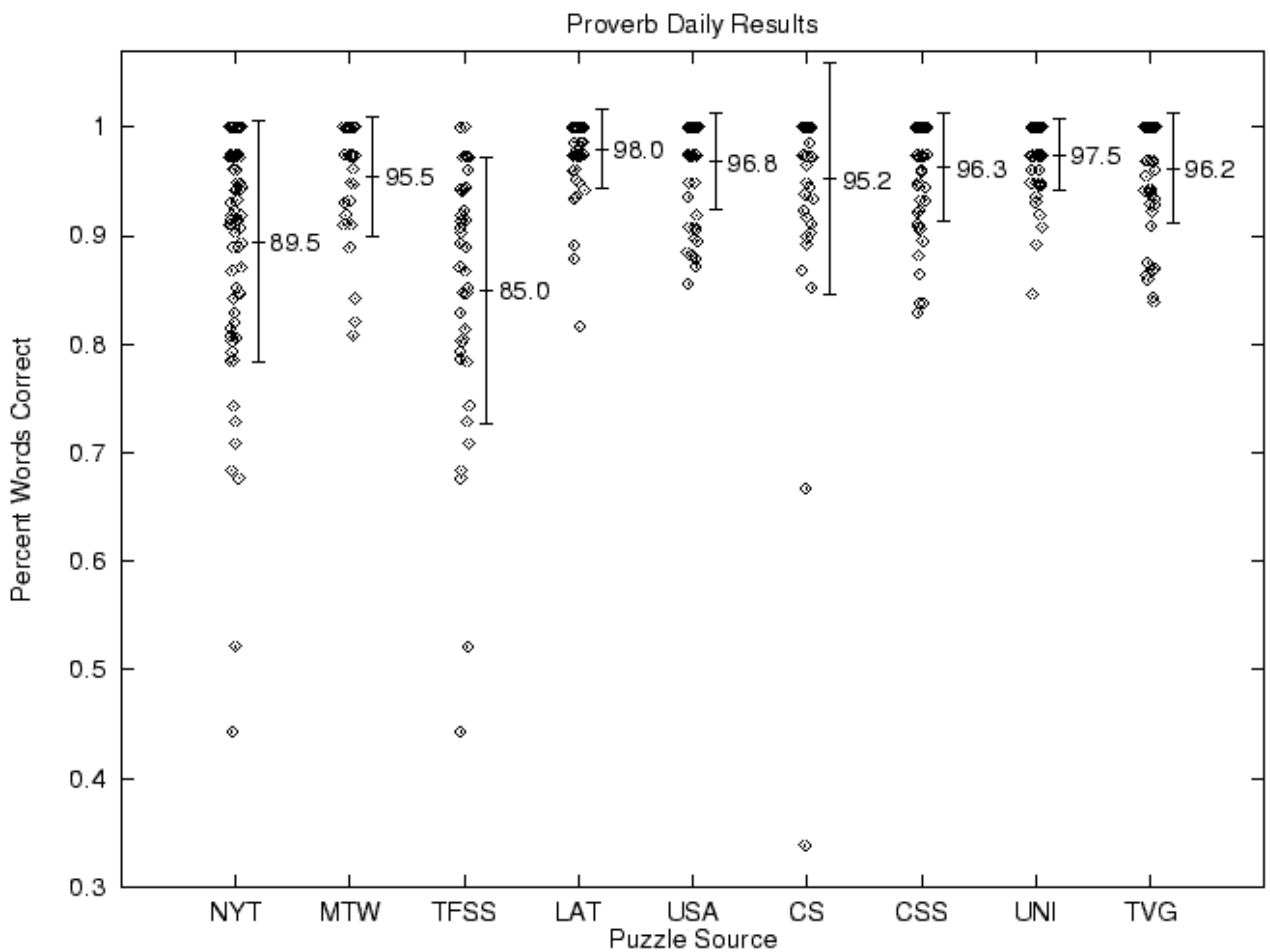
CSPs: Crossword puzzles

Daily Puzzles

370 puzzles from 7 sources.

Summary statistics:

- 95.3% words correct (miss three or four words per puzzle)
- 98.1% letters correct
- 46.2% puzzles completely correct



Source: Michael Littman

CSP/logic: Formal verification

Hardware verification

Software verification

Most progress in the last 10 years based on:
Encodings into propositional satisfiability (SAT)

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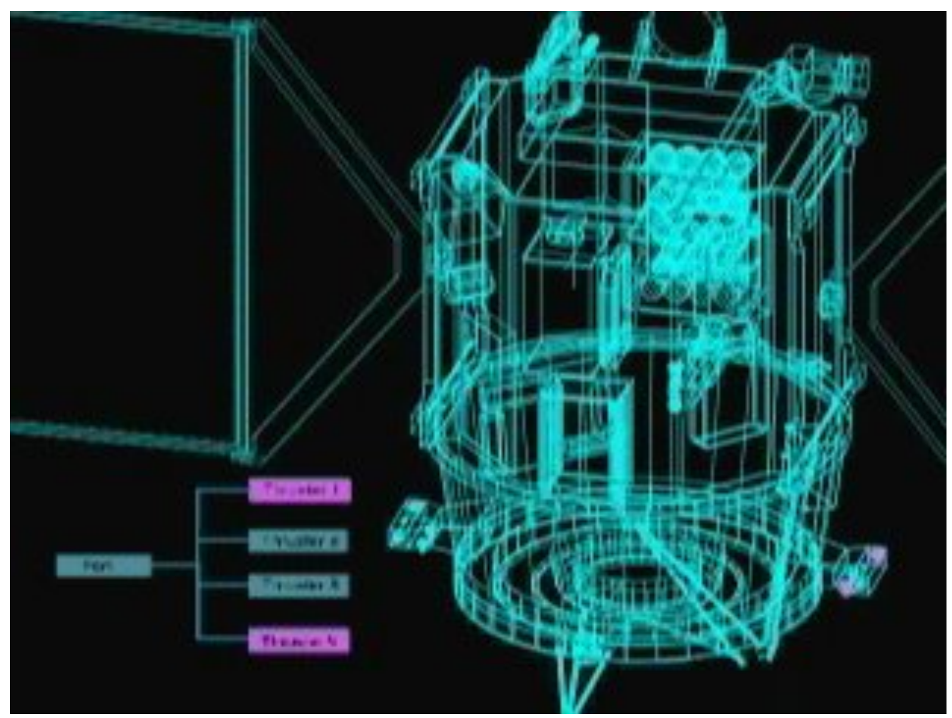
Planning: Spacecraft control

NASA: Deep Space One spacecraft operated autonomously for two days in May, 1999:

- determined its precise position using stars and asteroids despite a malfunctioning ultraviolet detector
- planned the necessary course adjustment
- fired the ion propulsion system to make this adjustment



Source: NASA

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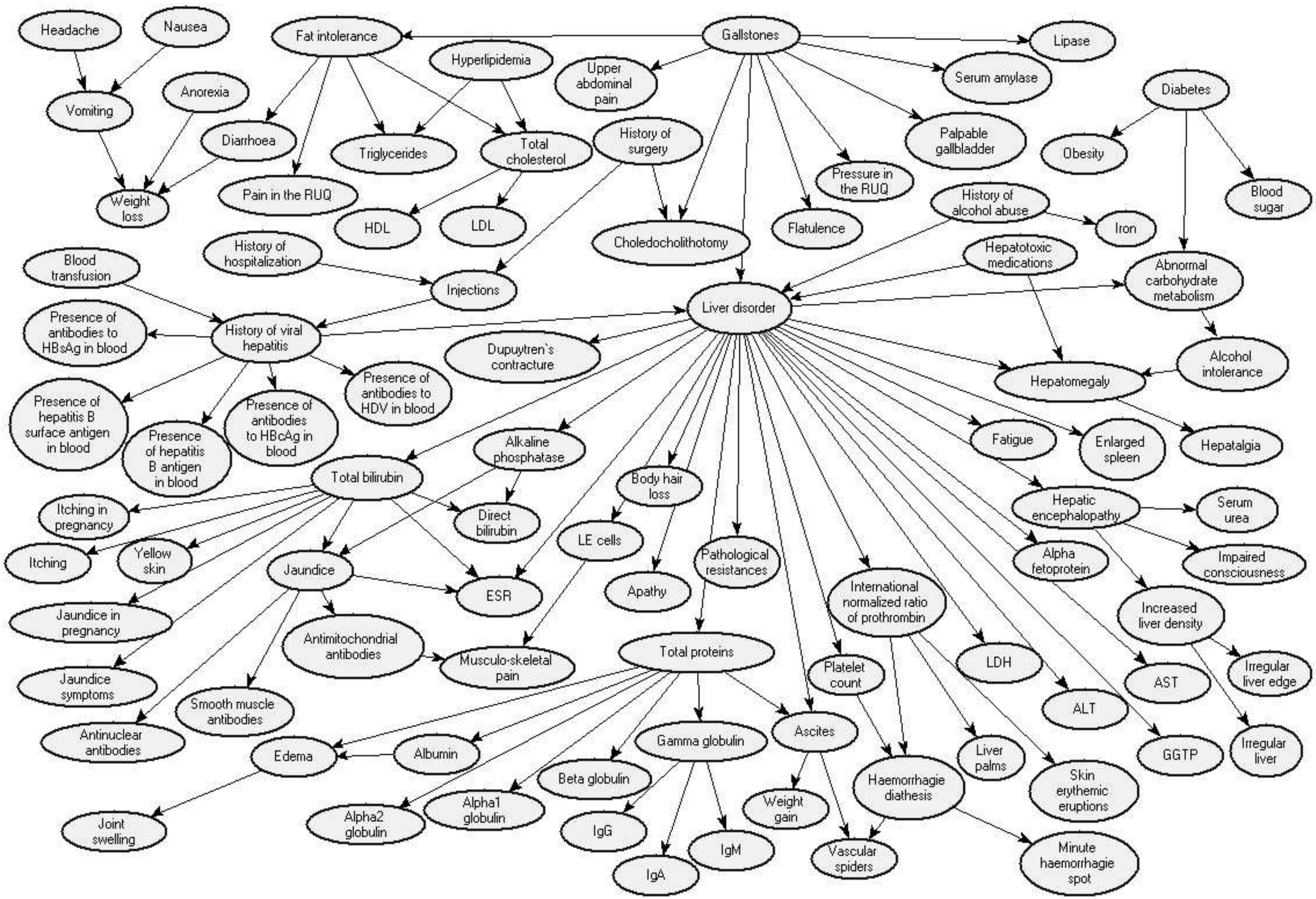
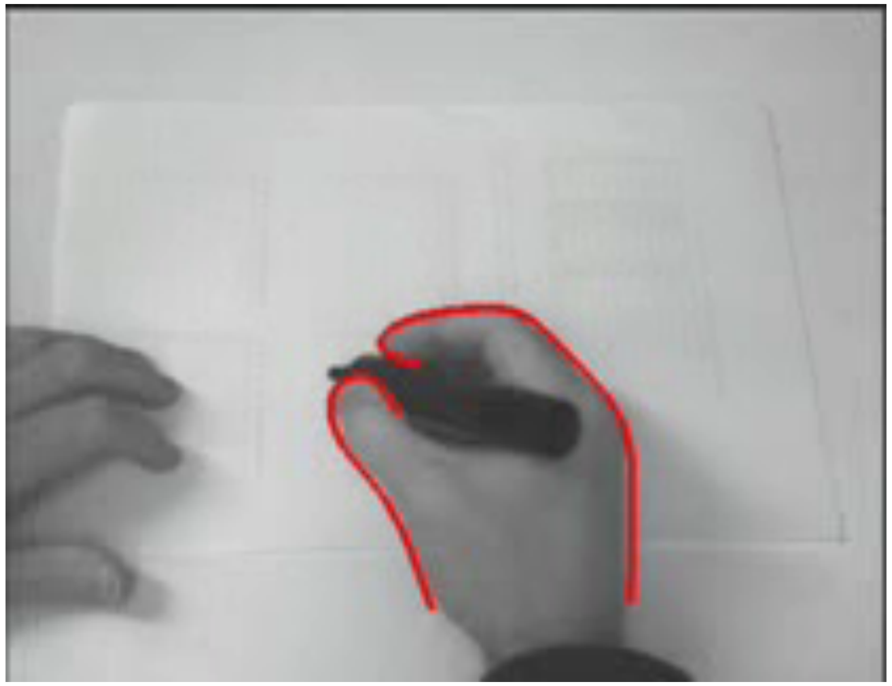
Bayes Net to diagnose liver disease



Onisko et al., 99

Reasoning under uncertainty

Motion tracking: track a hand and estimate activity:
drawing, erasing/shading, other



Source: Kevin Murphy, UBC

Some examples we may refer to

- Read carefully Section 1.6 on textbook: "Example Applications"
    - Tutoring system
    - Trading agent
    - Autonomous delivery robot
    - Diagnostic assistant

Review of learning outcomes

Do you feel comfortable with these now?

- discuss different representational dimensions (e.g., deterministic and stochastic)
- assess the size of the state space of a given problem
- discuss some AI applications