REASONING AND INFERENCE

Part I: Review of Problem Spaces and Inference Chains

Characteristics of Goal-driven Problems

- Many initial conditions
- Only a few outcome states
- E.g., classification or diagnostic problems

Classification Type Problem Space
Problem Solving and Inferencing

Characteristics of Data-driven Problems

- Few initial conditions, constraints or values
- Many possible outcome states
- E.g., design or planning problems

Design/Planning Problem Space

Initial Conditions  Intermd. Conditions  Solutions or Goals

Custom Design or Plan

Question

- What allows us to link states.....?

Part II: Rules of Logical Inference
Problem Solving and Inferencing

Reasoning and Inference

• We assume that connections between initial and final states exist
• Links between states must adhere to certain rules
• Linkages can be determined by application of appropriate rules
  - >>>> This process is known as reasoning or logical inference

Some Methods of Inference

• Many ways to draw inferences:
  - Deduction
  - Induction
  - Other Means

Deduction

• Given an initial postulate, other knowledge can be deduced
  - e.g., Given P = "Absolute uniform motion cannot be detected" and Q = "The speed of light is independent of the motion of the source."
  - Deduction = > "Speed of light in a vacuum is constant for all observers."
  - Deduction = > "Time dilates and length contracts as the speed of light is approached."
  - Deduction = > "Two moving clocks can not be synchronized."

Induction

• Given a set of specific instances, we generalize to all states and conditions
  - e.g., Measurements of planetary motion by Tyco Brahe in the 1500’s
  - Kepler (1620) induced: "All planets move in elliptical orbits."
**Other Means of Inference**

- Generate and Test (trial and error)
- Abduction
  - Reasoning from a true conclusion to a premise (faulty)
- Default
  - Assume a general or common conclusion
- Analogy
  - Assume current problem is similar to a previous or different case
- Intuition (gut feel)

**Pragmatic Application of Deduction**

- Deduction is most useful form of inference for expert systems
- Example: What can we conclude given the following?
  - We know A is true and have the rules: $A \rightarrow B; B \rightarrow C$
  - Answer: B is true and C is true ($A \rightarrow C$)
  - Answer: Modus Ponens

**Modus Ponens**

- If the premise is true then the conclusion is true.
- We know A implies B ($A \rightarrow B$). Thus: if A is true, then B MUST be true
- Caveat: Asymmetrical relationship
  - E.g., if B is true, then A is NOT necessarily true
- Similarly, if B is true, then C MUST be true.
  - Logically we can conclude that $A \rightarrow C$. 

**Modus Ponens (example)**

- If an animal gives live birth, then it is a mammal ($A \rightarrow B$)
- Thus, if we know that a life form gives birth to live animals (A), then we CAN state with confidence that it is a mammal (B).
- However, we CAN NOT claim that if an animal is known to be a mammal (B), then it must give live birth (e.g., platypus) (A)
- Similarly, if a life form is a mammal (B), then it has warm blood ($B \rightarrow C$)
- We can also conclude that if an animal gives live birth, that it has warm blood ($A \rightarrow C$)
Problem Solving and Inferencing

Importance of Modus Ponens

- Provides a means to legitimately reason between states
  - IF A→B...B→H...H→M...M→X...X→Z
  - THEN A→Z
- Can be implemented as a problem solving strategy in expert systems....

Part III: Problem Solving Strategies and Tactics

Algorithms for Conducting Searches

- Forward chaining
  - Start with the initial conditions and work through each chain of rules to conclusion
- Backward chaining
  - Start with goal and work back to initial conditions associated with goal
- Hybrid chaining
  - Execute both backward and forward chaining in the same problem
- All work but some are optimal

Forward Chaining eg

System Goals: PRINTER? RESTOCK PAPER?

Q: What is paper inventory? (low)
Q: publications needed? (yes)
Q: publications needed? (no)
Q: quality? (high)
Q: quality? (low)
Q: quality? (high)
Q: quality? (low)

RULE Number, 1, If paper inventory=low Then RESTOCK PAPER=yes
RULE Number, 2, If paper inventory=high Then RESTOCK PAPER=no
RULE Number, 3, If quality=high quality then PRINTER=Laser
RULE Number, 4, If quality=low quality then PRINTER=Inkjet
RULE Number, 5, If publications=yes then quality=high quality
RULE Number, 6, If publications=no Then quality=low quality
Problem Solving
and Inferencing

**Backward Chaining eg**

System Goals: PRINTER?  
RESTOCK PAPER?

<table>
<thead>
<tr>
<th>RULE Number</th>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>If quality=high quality then PRINTER=Laser</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>If publications=yes then quality=high quality</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Q: publications needed? (yes)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>If publications=no Then quality=low quality</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Q: What is paper inventory? (low)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>If paper inventory=low Then RESTOCK PAPER=yes</td>
<td></td>
</tr>
</tbody>
</table>

**Summary**

- Different problems map on to different problem spaces
- Goal-driven problems start with many initial conditions and "funnel" down
- Data-driven problems start with a few initial conditions and expand to many possibilities
- Links between states are provided by modus ponens

**Summary (cont2)**

- Algorithms guide the search process
- Backward and forward chaining work for ALL problems
- Backward chaining algorithms are optimized for goal-driven problems
- Forward chaining algorithms are optimized for data-driven problems
- XDESK's default is back chaining, but will forward chain in the absense of information

**Backward and forward chaining demos**

- Run infdemo.kbs using XDESK
end...