CSE 473
Artificial Intelligence
Review

Logistics
• Problem Set due at midnight
• Exam next Wed 8:30—10:30
  Regular classroom
  Closed book
  Cover all quarter’s material
  Emphasis on material not covered on midterm
  • Even more emphasis on material not on any PS

Abalone

Defining AI
human-like vs rational

<table>
<thead>
<tr>
<th>Systems that think like humans</th>
<th>Systems that think rationally</th>
</tr>
</thead>
<tbody>
<tr>
<td>thought</td>
<td>behavior</td>
</tr>
</tbody>
</table>

Goals of this Course
• To introduce you to a set of key:
  Paradigms &
  Techniques
• Teach you to identify when & how to use
  Heuristic search
  Constraint satisfaction
  Machine learning
  Logical inference
  Bayesian inference
  Policy construction

Theme I
• Problem Spaces & Search
  How to specify PS?
  Two kinds of search?
Learning as Search

SUPPLE - Adapting UIs

Adapting to Device Characteristics

Interface Adaptation as Search

Theme II

- In the knowledge lies the power
- Adding knowledge to search?

Heuristics

- How to generate?
- Admissibility?
Constraint Satisfaction?

- How to Specify?

```
SEND
+ MORE
------
MONEY
```

- Why Effective?

Backjumping (BJ)

- Similar to BT, but
  more efficient when no consistent instantiation
  can be found for the current var
- Instead of backtracking to most recent var...
  BJ reverts to deepest var which was c-checked
  against the current var

BJ Discovers
(2, 5, 3, 6) inconsistent with x0
No sense trying other values of x0

Shuttle Repair Scheduling

Probabilistic Representations

- How encode knowledge here?

In the knowledge lies the power

Theme III
Importance of Representation

- Features in ML
- Reformulation

Propositional. Logic vs. First Order

<table>
<thead>
<tr>
<th>Ontology</th>
<th>Facts (P, Q)</th>
<th>Objects, Properties, Relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syntax</td>
<td>Atomic sentence Connectives</td>
<td>Variables &amp; quantification Sentences have structure: terms father-of(mother-of(X))</td>
</tr>
<tr>
<td>Semantics</td>
<td>Truth Tables</td>
<td>Interpretations (Much more complicated)</td>
</tr>
<tr>
<td>Inference Algorithm</td>
<td>DPLL, GSAT Fast in practice</td>
<td>Unification Forward, Backward chaining Prolog, theorem proving</td>
</tr>
<tr>
<td>Complexity</td>
<td>NP-Complete</td>
<td>Semi-decidable</td>
</tr>
</tbody>
</table>
**Nested Quantifiers:**
*Order matters!*
\[ \forall x \exists y P(x,y) \neq \exists y \forall x P(x,y) \]

Every dog has a tail
\[ \forall d \exists t \text{ has}(d,t) \quad \exists t \forall d \text{ has}(d,t) \]

**Logical Inference as Search**

**Skolemization**
- Existential quantifiers aren’t necessary!
  - Existential variables can be replaced by:
    - Skolem functions (or constants)
    - Args to function are all surrounding \( \forall \) vars

- \( \forall d \exists t \text{ has}(d,t) \)
  \[ \forall d \text{ has}(d,f(d)) \]
- \( \exists x \forall y \text{ loves}(y,x) \)
  \[ \forall y \text{ loves}(y,f(y)) \]
  \[ \forall y \text{ loves}(y,f97) \]

**Why is Learning Possible?**
Experience alone never justifies any conclusion about any unseen instance.

Learning occurs when PREJUDICE meets DATA!

Learning a “FOO”

**Planning**
- Extend to Durative Actions
  - Simultaneous actions
  - Minimize make-span

- How???

**Uncertainty**
- Joint Distribution
- Prior & Conditional Probability
- Bayes Rule
- [Conditional] Independence
- Bayes Net
Dynamic Bayesian Network
State Estimation

Specifying a MDP
S = set of states set (|S| = n)
A = set of actions (|A| = m)
Pr = transition function Pr(s,a,s') represented by set of m n x n stochastic matrices (factored into DBNs) each defines a distribution over SxS
R(s) = bounded, real-valued reward fun represented by an n-vector

Finding a Policy
• Value Iteration
• Policy Iteration
• Modified Policy Iteration

Bellman Backup

Q-Learning
• Maintain Q(a, s) for visited states, tried actions
• As execute actions, do backup on per-action basis

Q(s,a) ← Q(s,a) + α[R(s) + γ \max_a Q(s',a') - Q(s,a)]
• Or compute weighted average over all future states (not just immediate successor)
• Do updates at end of epoch
• Approximating Q function

And More
• Specific search & CSP algorithms
• Adversary Search
• Inference in Propositional & FO Logic
• Specific Learning Algorithms
  • DT Induction, Ensembles, Naïve Bayes
• EM, DBNs
• Lots of details