CSE 473
Artificial Intelligence

Review

Logistics

- Project due tonight
- Exam next Mon 2:30—4:20
  - Regular classroom
  - Closed book
  - Cover all quarter's material
  - Emphasis on material not covered on midterm

Defining AI

<table>
<thead>
<tr>
<th>thought vs. behavior</th>
<th>human-like vs. rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems that think like humans</td>
<td>Systems that think rationally</td>
</tr>
<tr>
<td>Systems that act like humans</td>
<td>Systems that act rationally</td>
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</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, Planning, Logical inference, Bayesian inference, Policy construction, Machine learning
Theme I

- Problem Spaces & Search

Learning as Search

- Decision trees
- Structure learning in Bayesian networks
- Unsupervised clustering
- Boosting

Theme II

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

Heuristics

- How to generate?
- Admissibility?
## 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 sentences, 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, WalkSAT</td>
<td>Unification, Forward, Backward chaining, Resolution, theorem proving</td>
</tr>
<tr>
<td>Complexity</td>
<td>NP-Complete</td>
<td>Semi-decidable</td>
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### Planning
- Problem solving algorithms that operate on explicit propositional representations of states and actions.
- Make use of specific heuristics.
- State-space search: forward (progression) / backward (regression) search
- Partial order planners search space of plans from goal to start, adding actions to achieve goals
- GraphPlan: Generates planning graph to guide backwards search for plan
- SATplan: Converts planning problem into propositional axioms. Uses SAT solver to find plan.

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## Probabilistic Representations

- How encode knowledge here?

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## Uncertainty

- Joint Distribution
- Prior & Conditional Probability
- Bayes Rule
- [Conditional] Independence
- Bayes Net

  - Propositional
  - Hot topic: extensions to FOL

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In the knowledge lies the power
### Localization as Dynamic Bayes Net

\[
P(b | j, m) = \alpha \sum_{e, a} P(b, j, m, e, a)
\]

### Markov Assumption Helps!

\[
P(b | j, m) = \alpha P(b) \sum_{e} P(e) \sum_{a} P(a | b, e) P(j | a) P(m | a)
\]
Representations for Bayesian Robot Localization

Discrete approaches ('95)
- Topological representation ('95)
- uncertainty handling (POMDPs)
- occasional global localization, recovery
- Grid-based, metric representation ('96)
- global localization, recovery

Kalman filters (late-80s?)
- Gaussians
- approximately linear models
- position tracking

Particle filters ('99)
- sample-based representation
- global localization, recovery

Multi-hypothesis ('00)
- multiple Kalman filters
- global localization, recovery

Sensor board: Data Stream

Example Evaluation Run

Decision stumps classifiers (at 4Hz)
HMM with probabilities as inputs (using a 15 second sliding window with 5 second overlap)
Ground truth for a continuous hour and half segment of data.

Specifying an 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
each defines a distribution over S x S

R(s) = bounded, real-valued reward function
represented by an n-vector
Bellman Backup, Value Iteration

Stochastic, Fully Observable

Why is Learning Possible?

Experience alone never justifies any conclusion about any unseen instance.

Learning occurs when PREJUDICE meets DATA!

Inductive learning method

- Construct/adjust $h$ to agree with $f$ on training set ($h$ is consistent if it agrees with $f$ on all examples)
- E.g., curve fitting:

  \[ f(x) \]

- Ockham's razor: prefer the simplest hypothesis consistent with data
Decision Tree Overfitting

Accuracy

On training data
On test data

Number of Nodes in Decision tree

ANEMIA PATIENTS AND CONTROLS

Red Blood Cell Volume
Red Blood Cell Hemoglobin Concentration

EM ITERATION 1

EM ITERATION 3
And More

- Specific search & CSP algorithms
- Adversary Search
- Inference in Propositional & FO Logic
- Learning: decision trees, boosting, EM, RL
- Lots of details