Artificial Intelligence Recap
CSE P573

Mausam
What is intelligence?

- (bounded) Rationality
  - We have a performance measure to optimize
  - Given our state of knowledge
  - Choose optimal action
  - Given limited computational resources

- Human-like intelligence/behavior
Search in Discrete State Spaces

• This is different from Web Search 😊
• Every discrete problem can be cast as a search problem.
• (states, actions, transitions, cost, goal-test)
• Types
  – uninformed systematic: often slow
    • DFS, BFS, uniform-cost, iterative deepening
  – Heuristic-guided: better
    • Greedy best first, A*
    • relaxation leads to heuristics
  – Local: fast, fewer guarantees; often local optimal
    • Hill climbing and variations
    • Simulated Annealing: global optimal
    • Genetic algorithms: somewhat non-local due to crossing over
  – (Local) Beam Search
Search Example: Game Playing

- Game Playing
  - AND/OR search space (max, min)
  - minimax objective function
  - minimax algorithm (~dfs)
    • alpha-beta pruning
  - Utility function for partial search
    • Learning utility functions by playing with itself
  - Openings/Endgame databases
    • Secondary search/Quiescence search
Knowledge Representation and Reasoning

- Representing: what I know
- Reasoning: what I can infer

- CSP
- Logic

- Bayes Nets
- Markov Decision Process

- Decision Trees
- Neural Network
KR&R Example: Propositional Logic

• **Representation:** Propositional Logic Formula
  – CNF, Horn Clause, ...

• **Reasoning:** Deduction
  – Forward Chaining
  – Resolution

• **Model Finding**
  – Enumeration
  – SAT Solving
Search+KR&R Example: CSP

- **Representation**
  - Variables, Domains, Constraints

- **Reasoning: Constraint Propagation**
  - Node consistency, Arc Consistency, k-Consistency

- **Search**
  - Backtracking search: partial var assignments
    - Heuristics for choosing which var/value next
  - Local search: complete var assignments

- **Tree structured CSPs: polynomial time**

- **Cutsets**: vars assigned \(\rightarrow\) converts to Tree CSP
Search+KR&R Example: SAT Solving

- **Representation**: CNF Formula
- **Reasoning**
  - pure literals; unit clauses; unit propagation
- **Search**
  - DPLL (~ backtracking search)
    - MOM’s heuristic
    - Local: GSAT, WalkSAT
- **Advances**
  - Clause Learning: learning from mistakes
  - Restarts in systematic search
  - Portfolio of SAT solvers; Parameter tuning
- **Phase Transitions in SAT problems**
Search+KR&R Example: Planning

- **Representation**: STRIPS
- **Reasoning**: Planning Graph
  - Polynomial data structure
  - reasons about constraints on plans (mutual exclusion)
- **Search**
  - Forward: state space search
    - planning graph based heuristic
  - Backward: subgoal space search
  - Local: FF (enforced hill climbing)
- **Planning as SAT**: SATPlan
KR&R Part 2: Continuous Spaces

• Search
  – Gradient Descent
  – Newton Raphson
  – Optimization (convex/non-convex...)

• Constraint Optimization (we didn’t study this)
  – Linear Programming
  – Integer Linear Programming
  – Mixed Integer Linear Programming
KR&R: Probability

• **Representation:** Bayesian Networks
  – encode probability distributions compactly
    • by exploiting conditional independences

• **Reasoning**
  – Exact inference: var elimination
  – Approx inference: sampling based methods
    • rejection sampling, likelihood weighting, Gibbs sampling
KR&R: Hidden Markov Models

• Representation
  – Spl form of BN
  – Sequence model
  – One hidden state, one observation

• Reasoning/Search
  – most likely state sequence: Viterbi algorithm
  – marginal prob of one state: forward-backward
KR&R: One-step Decision Theory

- **Representation**
  - actions, probabilistic outcomes, rewards

- **Reasoning**
  - expected value/regret of action
  - Expected value of perfect information

<table>
<thead>
<tr>
<th>Actions</th>
<th>States of Nature</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Favorable Market</td>
</tr>
<tr>
<td>Large plant</td>
<td>$200,000</td>
</tr>
<tr>
<td>Small plant</td>
<td>$100,000</td>
</tr>
<tr>
<td>No plant</td>
<td>$0</td>
</tr>
</tbody>
</table>

- **Non-deterministic uncertainty**
  - Maximax, maximin, eq likelihood, minimax regret.

- **Utility theory: value of money...**
KR&R: Markov Decision Process

• Representation
  – states, actions, probabilistic outcomes, rewards
  – ~AND/OR Graph (sum, max)

• Reasoning: $V^*(s)$
  – Value Iteration: search thru value space
  – Policy Iteration: search thru policy space

• State space search
  – LAO* (AND/OR version of A*)
Learning: BNs/HMMs/NB

• ML estimation. $\max P(D | \theta)$
  – counting; smoothing
• MAP estimation $\max P(\theta | D)$
• Hidden data
  – Expectation Maximization (EM) {local search}

• Structure learning (BN)
  – Local search thru structure space
  – Trade off structure complexity and data likelihood

• HMM: Hidden State Space
  – Baum Welch (like EM)
Learning: Decision Tree

• Representation
  – tree with one variable at each node

• Reasoning
  – just follow the appropriate path

• Learning
  – Greedy search: split one var at a time
    • post pruning/early stopping
Learning: Perceptron

- **Representation**: perceptron

- **Learning**
  - local search in weight space to minimize errors
  - contrast with SVM
    - maximize margin from support vectors

- **Perceptron**: linear separator

- **Neural network**: layers of perceptrons
Learning: Nearest neighbor

• **Representation**: none!

• **Reasoning**: weighted average of k-nearest pts

• **Learning**: none!

• can represent any decision boundary
  – requires huge data (needs all space to be filled)
  – makes error close to boundary
Agents

What world was like

Learn how world evolves

Learn what my actions do

Learn utility function

what world is like now

what it'll be like if I do acts A1-An

How happy would I be?

what action should I do now?

Feedback

Sensors

Effectors

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Popular Themes

• Weak AI vs. Strong AI

• Syntax vs. Semantics

• Logic vs. Probability
Weak AI vs. Strong AI

• Weak – general methods
  • primarily for problem solving
  • A*, CSP, Bayes Nets, MDPs...

• Strong -- knowledge intensive
  – more knowledge ⇒ less computation
  – achieve better performance in specific tasks
  – POS tagging, Chess, Jeopardy
Syntax vs. Semantics

• Syntax: what can I say
  – Sentence in English
  – Logic formula in Prop logic
  – CPT in BN

• Semantics: what does it mean
  – meaning that we understand
  – $A \land B$: both $A$ and $B$ are true
  – Conditional independence …
Logic vs. Probability

- Discrete || Continuous
- Hill climbing || Gradient ascent
- SAT solving || BN inference
- Tree structured CSP || Polytree Bayes nets
- Cutset || Cutset
- Classical Planning || Factored MDP
- Bellman Ford || Value Iteration
- A* || LAO*
Advanced Ideas in AI

• Factoring state/actions...
• Hierarchical decomposition
  – Hierarchy of actions
• Approximation by sampling
  – Markov Chain Monte Carlo
  – UCT algorithm: game playing
  – Particle filters: belief tracking in robotics
• Context sensitive independence
  – Cutsets
  – Backbones in logic
• Combining probability and logic
  – Markov Logic Networks, Probabilistic Relational Models
AI we didn’t cover

- Ontologies
- Information retrieval/web search
- Robotics
- Vision
- Mechanism design
- Computational Neuroscience
- Reinforcement learning
- ...

Applications of AI

- **Sumit**: automatic accompaniment of music
  - probabilistic reasoning, machine learning (HMMs)
- **Ashish**: hardware/software verification, combinatorial design, subprobs in many domains
  - SAT solving
- **Joseph**: fraud detection, market/risk assessment, personalization, recommender systems...
  - Machine learning
- **Matthai**: elderly care
  - Machine learning, probabilistic reasoning
Applications of AI

• Mars rover: planning
• Jeopardy: NLP, info retrieval, machine learning
• Puzzles: search, CSP, logic
• Chess: search
• Blackjack: MDP
• Text categorization: machine learning

• Self-driving cars: robotics, prob. reasoning, ML...
Ethics of Artificial Intelligence

- Robots
  - Robot Rights
  - Three Laws of Robotics
- AI replacing people jobs
  - Any different from industrial revolution?
- Ethical use of technology
  - Dynamite vs. Speech understanding
- Privacy concerns
  - Humans/Machines reading freely available data on Web
  - Gmail reading our news
- AI for developing countries/improving humanity
AI-Centric World 😊

- Graphics
- Operations Research
- Linguistics
- Algorithms Theory
- AI
- Robot Design
- Databases
- Statistics
- Psychology Neurosc.