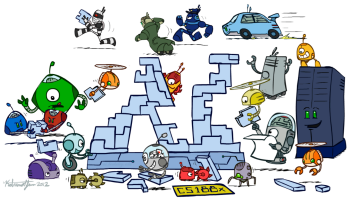
CS 473: Artificial Intelligence
Conclusion



Dieter Fox – University of Washington

[Many of these slides were created by Dan Klein and Pieter Abbeel for CS188 Intro to AI at UC Berkeley. All CS188 materials are available at http://ai.berkeley.edu.]

Exam Topics

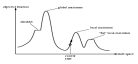
- Search
  - Problem spaces
  - BFS, DFS, UCS, A* (tree and graph), local search
  - Completeness and Optimality
  - Heuristics: admissibility and consistency; pattern DBs
- CSPs
  - Constraint graphs, backtracking search
  - Forward checking, AC3 constraint propagation, ordering heuristics
- Games
  - Minimax, Alpha-beta pruning,
  - Expectimax
  - Evaluation Functions
- MDPs
  - Bellman equations
  - Value iteration, policy iteration
- Reinforcement Learning
  - Exploration vs Exploitation
  - Model-based vs. model-free
  - Q-learning
  - Linear value function approx.
  - Inverse optimal control
- Hidden Markov Models
  - DBNs
  - Forward algorithm
  - Particle Filters
- Bayesian Networks
  - Basic definition, independence (d-sep)
  - Variable elimination
- Learning
  - BN parameters with complete data
  - Search through space of BN structures
  - Expectation maximization

What is intelligence?

- (bounded) Rationality
  - Agent has a performance measure to optimize
  - Given its state of knowledge
  - Choose optimal action
  - With limited computational resources
- Human-like intelligence/behavior

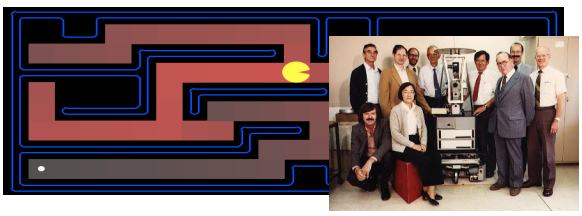
Search in Discrete State Spaces

- 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



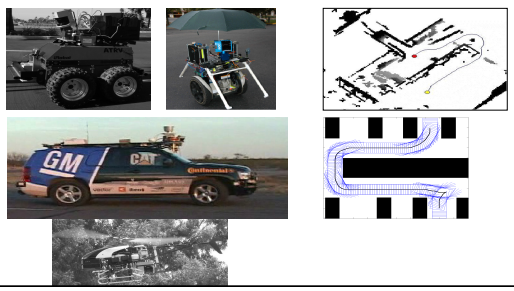
Which Algorithm?

- A*, Manhattan Heuristic

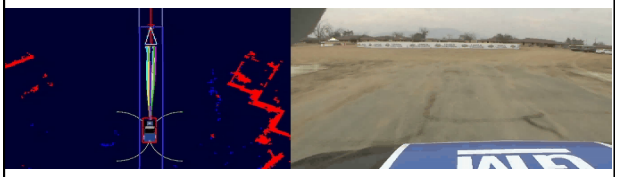


Motion/Path Planning

Examples (of what is usually referred to as path planning):

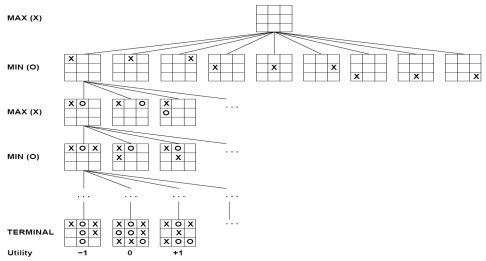


Example



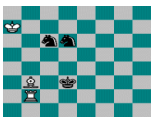
*Urban Challenge Race, CMU team, planning with Anytime D**

Adversarial Search



Adversarial Search

- 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



Knowledge Representation and Reasoning

- Representing: what agent knows

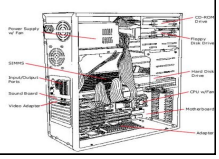
  Propositional logic
  Constraint networks
  HMMs
  Bayesian networks
  …

- Reasoning: what agent can infer

  Search
  Dynamic programming
  Preprocessing to simplify

Search+KR&R Example: CSP

- Representation
  - Variables, Domains, Constraints
- Reasoning:
  - Arc Consistency (k-Consistency)
  - Solving
    - Backtracking search: partial var assignments
      - Heuristics: min remaining values, min conflicts
    - Local search: complete var assignments



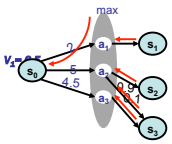
KR&R: Markov Decision Process

- Representation
  - states, actions, probabilistic outcomes, rewards

$$V^*(s) = \max_a Q^*(s,a)$$

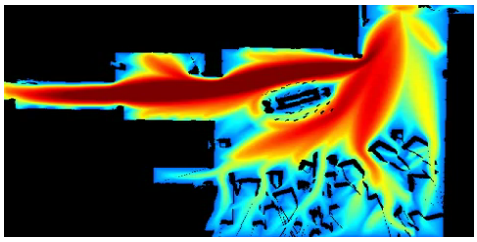
$$Q^*(s,a) = \sum_{s'} T(s,a,s')\left[R(s,a,s') + \gamma V^*(s')\right]$$

- Reasoning: V*(s)
  - Expectimax
  - Value Iteration: dynamic programming
- Reinforcement Learning:
  - Exploration / exploitation
  - Learn model or learn Q-function?

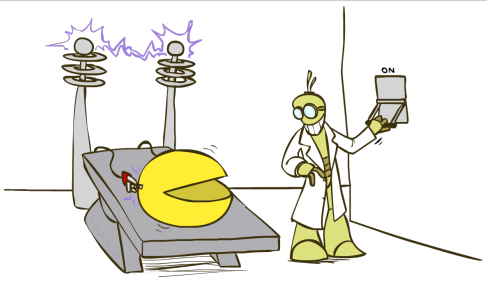


IOC: Pedestrian Trajectory Prediction

Pedestrian Trajectory Prediction



Pac-Man Beyond the Game!



Pacman: Beyond Simulation?



ROOMBA PACMAN

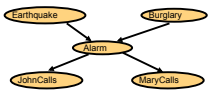
Students at Colorado University: http://pacman.elstonj.com

[VIDEO: Roomba Pacman.mp4]

Pacman: Beyond Simulation!

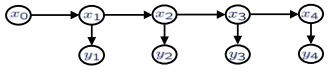
KR&R: Probability

- 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, MCMC/Gibbs



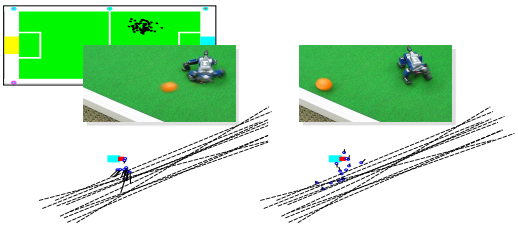
KR&R: Hidden Markov Models

- Representation
  - Sequence model
  - One hidden state, one observation

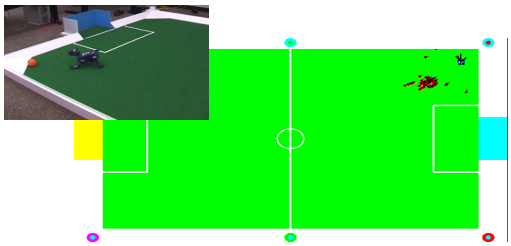


- Reasoning/Search
  - most likely state sequence: Viterbi algorithm
  - marginal prob of one state: forward-backward

Ball-Environment Interaction



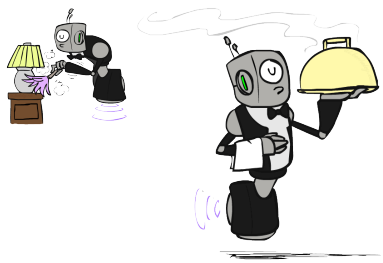
Ball-Environment Interaction



Learning Bayes Networks

- Learning Structure of Bayesian Networks
  - Search through space of BN structures
- Learning Parameters for a Bayesian Network
  - Fully observable variables
    - Maximum Likelihood (ML), MAP & Bayesian estimation
    - Example: Naïve Bayes for text classification
  - Hidden variables
    - Expectation Maximization (EM)

Personal Robotics



PR2 (autonomous)

[VIDEO: 5pile_200x.mp4]

[Maitin-Shepard, Cusumano-Towner, Lei, Abbeel, 2010]

Where to Go Next?

That's It!

- Help out with some course evaluations
- Have a great summer, and always maximize your expected utilities!