

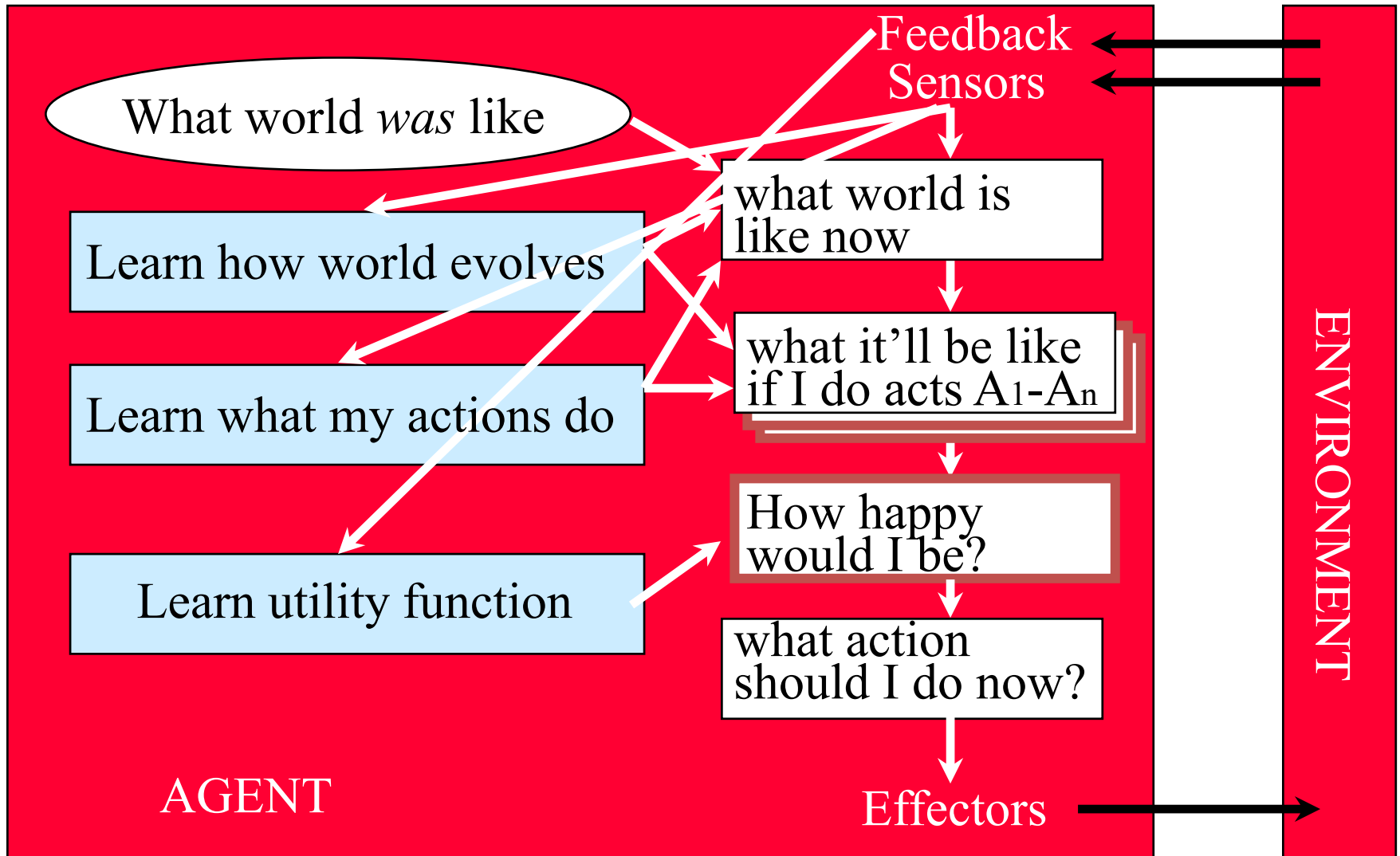
# Artificial Intelligence Recap

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

# Learning agents



# 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

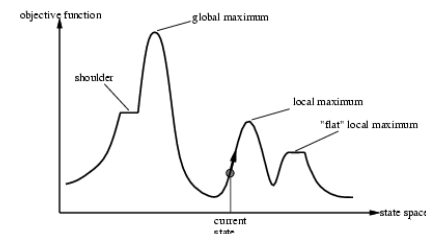
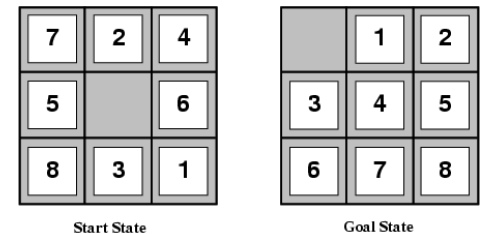
– **Heuristic-guided:** better

- 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
  
- Logic
  
- CSPs
  
- Bayes Nets

# 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)

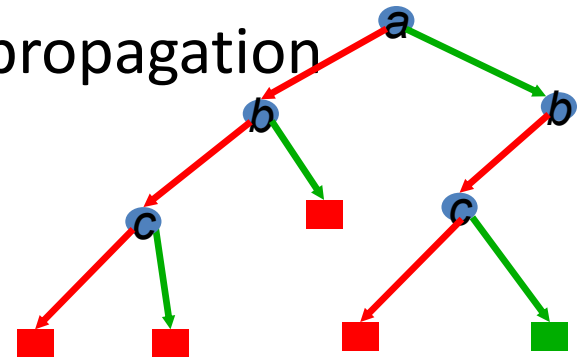
- MOM's heuristic

- Local: GSAT, WalkSAT

- **Advances**

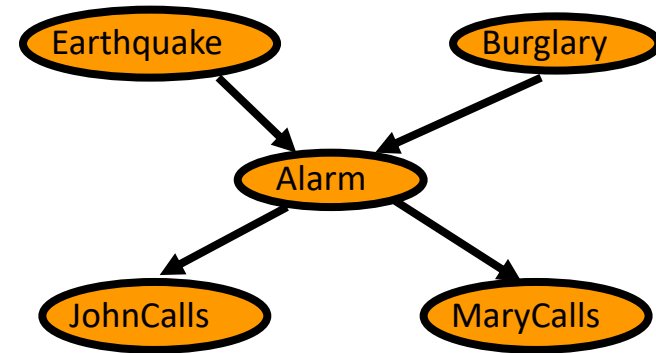
- Restarts in systematic search

- Phase Transitions in SAT problems



# 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: One-step Decision Theory

- **Representation**

- actions, probabilistic outcomes, rewards

- **Reasoning**

- expected value/regret of action

- Expected value of perfect information

<b>Actions</b>	<b>States of Nature</b>	
	<b>Favorable Market</b>	<b>Unfavorable Market</b>
<b>Large plant</b>	<b>\$200,000</b>	<b>-\$180,000</b>
<b>Small plant</b>	<b>\$100,000</b>	<b>-\$20,000</b>
<b>No plant</b>	<b>\$0</b>	<b>\$0</b>

- **Non-deterministic uncertainty**

- Maximax, maximin, eq likelihood, minimax regret..

- **Utility theory: value of money...**

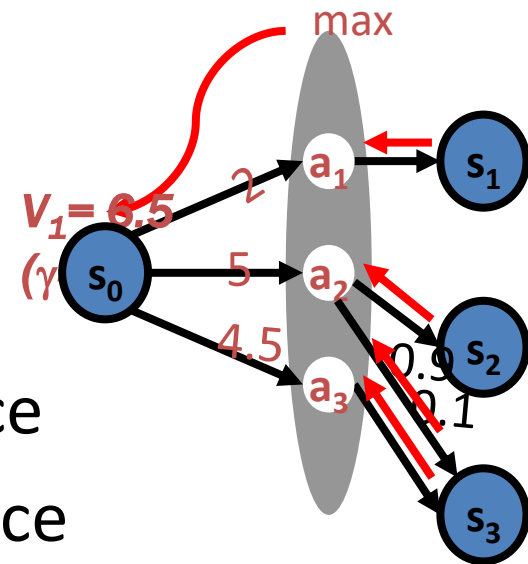
# KR&R: Markov Decision Process

- 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



# Learning: Bayes Nets

- ML estimation.  $\max P(D | \theta)$ 
  - counting; smoothing
- MAP estimation  $\max P(\theta | D)$ ..
  - Gradient descent
- Bayesian learning
  - $P(X | \mathbf{d}) = \sum_i P(X | \mathbf{d}, h_i) P(h_i | \mathbf{d}) = \sum_i P(X | h_i) P(h_i | \mathbf{d})$
- Hidden data
  - Expectation Maximization (EM) {local search}
- Structure learning (BN)
  - Local search thru structure space
  - Trade off structure complexity and data likelihood

# Learning: Neural Nets

- Representation

- Network of weighted sum + non-linearities

- Reasoning

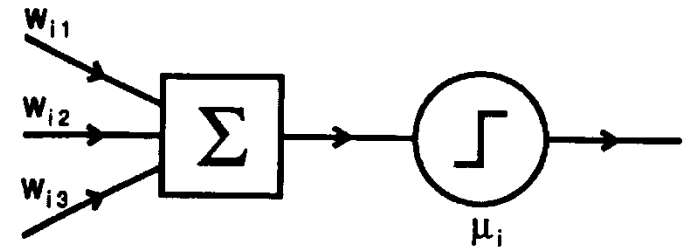
- Forward pass

- Learning

- Gradient descent

- Backpropagation through network

- Advantage: feature learning



# Learning: BNs/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

# Learning: Reinforcement Learning

- Learn model while taking actions
- What to learn
  - T and R: model based
  - Policy: Model free
- Which actions to take
  - Exploration – Exploitation
- Large state spaces
  - function approximation



# AI we didn't cover

- Temporal models: HMMs, Kalman filters...
- Ontologies
- Robotics
- Vision
- Mechanism design
- Multi-agent systems
- Sensor Networks
- Computational Neuroscience
- ...

# AI is about problems.

- It is an application-driven field
- Happy to beg, borrow, steal ideas from anywhere
- Traditionally discrete ... more and more cont.
- Traditionally logic... almost all probability
  - Recent close connections with EE/Stat due to ML
- HUGE field

# AI-Centric World 😊

Graphics

Algorithms  
Theory

Databases

Operations  
Research

AI

Statistics

Linguistics

Robot  
Design

Psychology  
Neurosc.

...