CSE 473

Chapter 13

A little bit of planning followed by uncertainty

Things we will devour today

- SATPlan
- Uncertainty – Why and how?
- Probability theory

The Last Word on Planning: SATPlan

- Idea: test the *satisfiability* of the logical sentence:
  (initial state) ∧ (all possible action descriptions for t steps) ∧ (goal achieved at step t)
- Create and test sentence for each t, t = 0, 1, 2, …, T_{max}
- Action descriptions include
  1. Successor-state axioms from situation calculus (superscript denotes t)
     E.g., $At(P1,JFK)^1 \Leftrightarrow (At(P1,SFO)^0 \wedge Fly(P1,SFO,JFK)^0) \vee (At(P1,JFK)^0 \wedge \neg Fly(P1,JFK,SFO)^0)$
  2. Precondition axioms E.g., $Fly(P1,SFO,JFK)^0 \Rightarrow At(P1,JFK)^0$
  3. State constraints.
     E.g., $\forall p, x, y, t \quad (x \neq y) \Rightarrow \neg(At(p,x)^t \wedge At(p,y)^t)$

Planning using SATPlan

- Sentence to be tested (for a particular t):
  (initial state) ∧ (all possible action descriptions) ∧ (goal)
- A model will assign true to actions that are part of correct plan and false to other actions
  If no plan exists, sentence will be unsatisfiable
- Use SAT solver such as DPLL or WalkSAT to test satisfiability (and find plan if one exists)
- SATPlan can handle large planning problems
  E.g., Up to 30-step plans in blocks world

Some Applications of Planning

- Assembly line planning at Hitachi
- Software procurement planning at Price Waterhouse
- Back-axle assembly planning at Jaguar Cars
- Logistics planning in the US Navy
- Scheduling mission-command sequences for satellites
- Observation planning for Hubble telescope
- Spacecraft control for Deep Space One probe
- Etc.

Planning Summary

§ Planning algorithms operate on explicit propositional representations of states/actions

§ STRIPS: restrictive propositional language

§ 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 sentence. Uses SAT solver to find plan.

That's nice but these algorithms assume complete knowledge of the world!

Hard to achieve in most cases

Enter…
Uncertainty

Example: Catching a flight

- Suppose you have a flight at 6pm
- When should you leave for SEATAC?
  - What are traffic conditions?
  - How crowded is security?

Dep time before 6pm	P(arrive-in-time)
20 min	0.05
30 min	0.25
45 min	0.50
60 min	0.75
120 min	0.98
1 day	0.99999

Probability Theory: Beliefs about events
Utility theory: Representation of preferences

Decision about when to leave depends on both:
Decision Theory = Probability + Utility Theory

What Is Probability?

- **Probability:** Calculus for dealing with nondeterminism and uncertainty
- **Probabilistic model:** Says how often we expect different things to occur
- Where do the numbers come from?
  - Frequentist view
  - Objectivist view
  - Subjectivist view

Why Should You Care?

- The world is full of uncertainty
  Logic is not enough
  Computers need to be able to handle uncertainty
- Probability: new foundation for AI (& CS!)
- Massive amounts of data around today
  Statistics and CS are both about data
  Statistics lets us summarize and understand it
  Statistics is the basis for most learning
- Statistics lets data do our work for us

Logic vs. Probability

Symbol: Q, R …	**Random variable:** Q …
Boolean values: T, F	**Values/Domain:** you specify e.g. {heads, tails} [1,6]
State of the world: Assignment of T/F to all Q, R … Z	**Atomic event:** a complete assignment of values to Q… Z • Mutually exclusive • Exhaustive
	Prior probability (aka Unconditional prob: P(Q)
	Joint distribution: Prob. of every atomic event