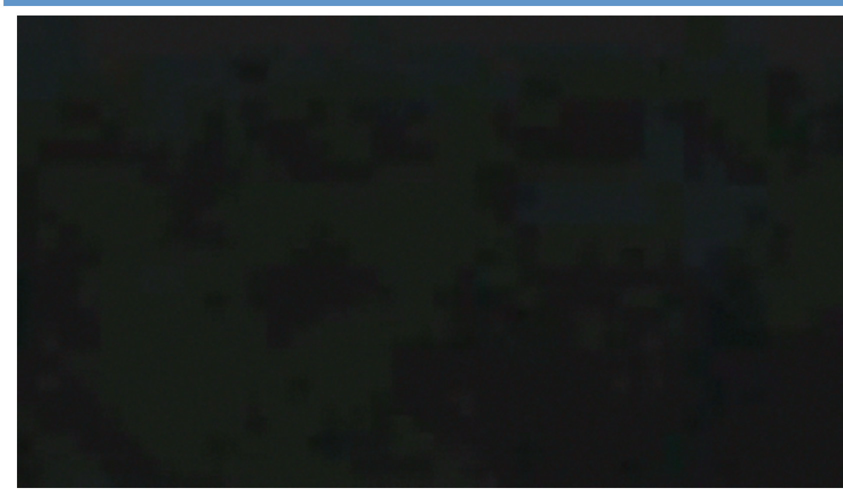
Planning

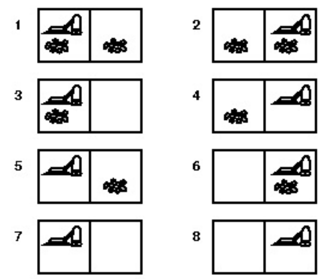
EECS 492
February 22nd, 2011

Meet Shakey



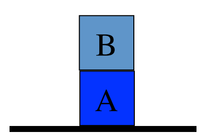
Planning

- What is planning?
  - Find a sequence of actions that achieves a desired result
  - Haven't we done planning already?
- Planning with TreeSearch
  - Initial state: our, well, initial state
  - Successor function: which actions can we perform?
  - isGoal: Have we achieved the desired state?



Sketch of an idea

- Let's say that we have some statements about the blocks world, like
  - On(B,A)
  - Clear(B)
  - On(A,T)
  - ~Clear(A)



- Can we "prove" that we can move block B?

  On(B,A) ^ Clear(B) => On(B,T) ^ Clear(A) (??)

- But adding this to the KB introduces contradictions!
  - E.g., Clear(A) ^ ~Clear(A)

Frame Axioms

"Time Is What Prevents Everything From Happening At Once.." - John Wheeler (1911-2008)

- An action divides time into a "before" and "after".
  - Different things are true---
  - Some are changed explicitly by the action
  - Some "continue to be"
- **Frame axioms:** The way we we describe the "after" in terms of the "before" and the action effects

John Wheeler
Manhattan Project Physicist

PDDL

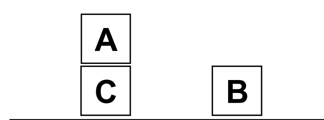
- Planning Domain Definition Language (PDDL)
  - Expresses typical frame axioms automatically
  - Database semantics
    - Closed world (fluents are false by default)
    - Two constants (Bob, Mr.Henderson) *always* refer to different objects
  - Based on STRIPS language (1971) used by Shakey
- Environment
  - fully observable, deterministic, finite, static, discrete
- Objectives
  - conjunctions of goal propositions

PDDL Action Schema

- Example:
  - **ACTION**: Fly(p, from, to)
  - **PRECOND**: At(p, from) ^ Plane(p) ^ Airport(from) ^ Airport(to)
  - **EFFECT**: -At(p, from) ^ At(p, to)
- In comparison to FOL
  - FOL: Variables (use unification), Predicates, Functions, arbitrary connectives
  - PDDL: Variables (use unification), Predicates, No functions, conjunctions only
- Goals
  - Cannot have a vacuum which wants at least one clean room: Clean(Room1) v Clean (Room2)
- Effects
  - Sets values of propositions (overriding earlier values)
  - Everything else "continues to be"

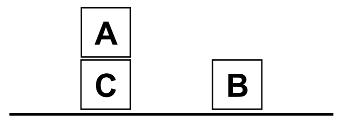
A Blocks-World Problem

- Initial:
  - On(A,C) ∧ On(B,Table) ∧ On(C,Table) ∧ Clear(A) ∧ Clear(B)
- Goal:
  - On(B,C)



- Define the clear predicate?
  - Clear(x) $\equiv \forall y.\ \neg$On(y,x)
  - But we can't: not part of the syntax of PDDL
  - Instead, values of Clear predicate are updated by actions

A Blocks-World Problem



On(A,C) ∧ On(B,Table) ∧ On(C,Table) ∧ Clear(A) ∧ Clear(B)

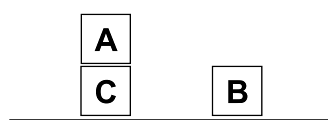
Move(*b*,*x*,*y*) *("move b from x to y")*

precondition: On(*b*,*x*) ∧ Clear(*b*) ∧ Clear(*y*)

effect: On(*b*,*y*) ∧ Clear(*x*) ∧ ¬On(*b*,*x*) ∧ ¬Clear(*y*)

- Consider goal state: On(B,C)
  - Can be unified with action Move(b,x,y)
    - θ = {b/A, x/C, y/B}
- Precondition satisfied?
- Resulting state
  - ¬ On(A,C) ∧ On(B,Table) ∧ On(C,Table) ∧ Clear(A) ∧ ¬ Clear(B) ∧ On(A,B) ∧ Clear (C)

A small problem



On(A,C) ∧ On(B,Table) ∧ On(C,Table) ∧ Clear(A) ∧ Clear(B)

Move(*b*,*x*,*y*) *("move b from x to y")*

precondition: On(*b*,*x*) ∧ Clear(*b*) ∧ Clear(*y*)

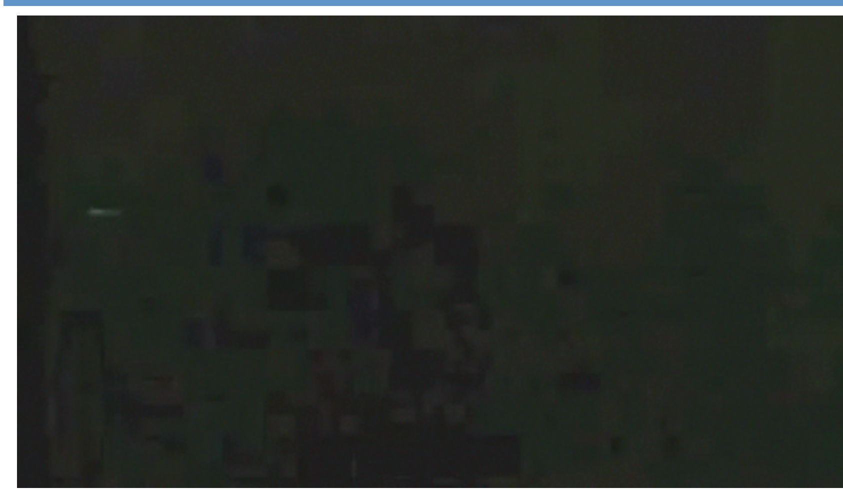
effect: On(*b*,*y*) ∧ Clear(*x*) ∧ ¬On(*b*,*x*) ∧ ¬Clear(*y*)

- What happens if we perform Move(b, x, Table)?
  - The table has a "special" property!
- How do we fix this?

Shakey the Robot

- Natural language interface
- STRIPS-style planner
  - Real-world implementation of blocks-world like problem

Shakey and STRIPS



Searching for Plans

- Given a plan (sequence of actions) and an initial state, can test whether plan achieves goal
- Q: How to *generate* solution plans?
- A: search (as always…)

Forward State-Space Search

- Also called progression planning
- Planning as state space search:
  - Represent states by sets of positive ground literals
    - Literals not appearing are false or don't matter
    - Initial state: given by planning problem
  - Action applicable in a state iff preconditions satisfied
  - Successor states generated by adding positive effect literals and deleting negative effect literals
  - Goal test succeeds iff state satisfies goal sentence
  - Step cost = 1 (typically)

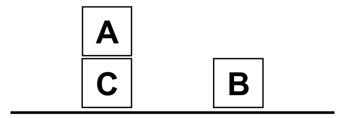
Forward Search: Complexity

- In the absence of function symbols, the state space of a planning problem is finite
  - Therefore any complete graph-search algorithm will be a complete planning algorithm
- But will it be efficient?
  - Many irrelevant actions
    - all applicable actions are considered in each state
  - What is branching factor for blocks world with *N* blocks?
  - Need good heuristic functions

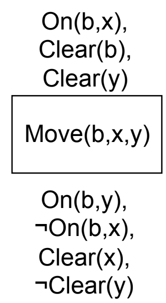
Backward State-Space Search

- Also called regression planning
- Generates *predecessors* starting from goal state
  - Find action *A* whose effect unifies with goal (or part)
  - New "goal" is set of conditions for this action to be applicable
  - Computing these conditions is called **regressing** the goal through the action.
  - Delete positive effects of A that appear in goal
  - Add precondition literals of A
- **Advantage**: need only consider relevant actions
- **Disadvantage**: dealing with interactions among goal propositions

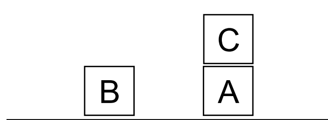
Regression Example



- Goal: On(B,C)
- Choose action:
  - Move(B,Table,C)
  - Achieves On(B,C), has preconditions Clear(B), Clear(C), On(B,Table)
- Choose action:
  - MoveToTable(A,C)
  - Achieves Clear(C), has preconditions Clear(A), On(A,C)
- Remaining conditions satisfied in initial state

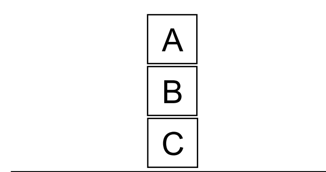


Sussman Anomaly (Linear Planning)



On(B,Table), Clear(B), Clear(C), On(C,A), On(A,Table)

Initial state



On(A,B), On(B,C)

Goal

Next Time

- Planning Graphs and real-world planning