1 handout: slides
Regression
We deliberate not about ends, but about means. For a doctor does not deliberate whether he shall heal, nor an orator whether he shall persuade, nor a statesman whether he shall produce law and order, nor does any one else deliberate about his end. They assume the end and consider how and by what means it is attained, and if it seems easily and best produced hereby; while if it is achieved by one means only they consider how it will be achieved by this and by what means this will be achieved, till they come to the first cause, which in the order of discovery is last... and what is last in the order of analysis seems to be first in the order of becoming. And if we come on an impossibility, we give up the search, for example, if we need money and this cannot be got; but if a thing appears possible we try to do it.

— Aristotle, *Nicomachean Ethics*, 350BC
Note that STRIPS has full initial state, partial goal state (= set). Search over sets of states!

**Initial node:** set of states in which goal is true

**Applicable:** at least one effect present, deletes not present, non-deleted preconditions present

**Child node:** remove adds, add preconditions

**Goal node:** subset of initial state

Doesn’t assume reversible actions

Lower branching factor?

Larger space ($3^n$ vs $2^n$)
Initial: $\text{At(Home)}, \text{Sells(HWS, Drill)}, \text{Sells(SM, Milk)}, \text{Sells(SM, Bananas)}$

**Go (here,there)**
- Pre: $\text{At(here)}$
- Post: $\text{At(there)}, \neg \text{At(here)}$

**Buy(store,$x$)**
- Pre: $\text{At(store), Sells(store, x)}$
- Post: $\text{Have(s)}$

Goal: $\text{At(Home), Have(Drill), Have(Milk), Have(Bananas)}$
Forward: states

- state known: strong heuristic, expressivity
- branching factor
- reachable states
- irrelevant states

Backward: sets of states

- relevant states
- unreachable states
- partial states: larger space, weaker heuristic, expressivity
- project proposals
- project presentations
- project papers
Partial-order Planning
Initial node: empty plan
Branch on all achievers of selected precondition
Branch on all threat resolutions
Goal node: plan without open preconditions
Initial: At(Home), Sells(HWS, Drill), Sells(SM, Milk), Sells(SM, Bananas)

**Go (here, there)**
- Pre: At(here)
- Post: At(there), ¬ At(here)

**Buy(store, x)**
- Pre: At(store), Sells(store, x)
- Post: Have(s)

Goal: At(Home), Have(Drill), Have(Milk), Have(Bananas)
Searching Plan-space

Principle of least commitment

**plan:** bindings, temporal links, causal links

**complete:** every precondition achieved, all vars instantiated

**consistent:** no temporal or binding contradictions

**threat:** potential clobber

refinement = adding actions and links
initialize plan to empty loop

pick unachieved precondition

find or add action to establish it

if no such, backtrack

add causal and temporal link for every threat

put threat before achiever or after dependent

if inconsistent, backtrack

for possible threats

add inequality constraint
For each new effect and each causal link check if effect unifies with \( \neg \) (condition of link)

For each new causal link and each step check if effect of step unifies with \( \neg \) (condition of link)

- refinement = adding actions and links
- achieve, establish, produce
- promote, demote, protect
- inequality, separation, non-codesignation
Principles

Causal links
- Limits search to relevant actions
- Easy plan modification and explanation

Least commitment
- Flexibility in choosing what to branch on
- Limits backtracking
- Smaller search space
- Allows more pruning of implicit plans
- Hard to find a good heuristic
Comparison

Forward: states
- + state known: strong heuristic, expressivity
- - branching factor
- - irrelevant states

Backward: sets of states
- + relevant states
- - partial states: larger space, weaker heuristic, expressivity

Partial-order: plans
- + small space
- +/− least commitment
- - poor heuristics
What question didn’t you get to ask today?
What’s still confusing?
What would you like to hear more about?

Please write down your most pressing question about AI and put it in the box on your way out.

Thanks!