Graph Plan

- A propositional planner, that is, there are no variables
- Simpler – don’t have to worry about matching
- Bigger – if you have six blocks, you need 36 propositions to represent all On(x,y) assertions

1. Make a plan graph of depth \( k \)
2. Search for a solution
3. If succeed, return a plan
4. Else \( k = k + 1 \)
5. Go to 1.

Plan Depth

A plan of depth \( k \)
- has \( k \) times steps
- may have multiple parallel actions per time step

\[
\begin{align*}
t = 1 & \quad \text{DoA} \quad \text{DoB} \\
t = 2 & \quad \text{DoC} \\
t = 3 & \quad \text{DoD} \quad \text{DoE}
\end{align*}
\]

Planning vs Scheduling

Planning: find steps and schedule
- PSPACE-complete

Graph Plan: find plans of a given depth

Scheduling: tasks are fixed
- NP-Complete
Making the Plan Graph

- Start with initial conditions
- Add actions with satisfied preconditions
Making the Plan Graph
• Start with initial conditions
• Add actions with satisfied preconditions
• Add all effects of actions at previous levels
• Add maintenance actions

0 1 2

0 1 2

0 1 2 3 4

0 1 2 3 4

0 1 2 3 4
Mutually Exclusive Actions

Two action instances at level i are mutex if:
- **Inconsistent effects**: effect of one action is negation of effect of another
- **Interference**: one action deletes the precondition of the other
- **Competing needs**: the actions have preconditions that are mutex at level i-1

Mutually Exclusive Propositions

Two propositions at level i are mutex if:
- **Negation**: they are negations of one another
- **Inconsistent support**: all ways of achieving the propositions at level i-1 are pairwise mutex.

Solution Extraction

- If all the literals in the goal appear at the deepest level and not mutex, then search for a solution for each subgoal at level i
- For each subgoal at level i
  - Choose an action to achieve it
  - If it’s mutex with another action, Fail
- Repeat for preconditions at level i-2

Birthday Dinner Example

- **Goal**: garb \(\land\) dinner \(\land\) present
- **Init**: garb \(\land\) clean \(\land\) quiet
- **Actions**:
  - **Cook**
    - Pre: clean
    - Effect: dinner
  - **Wrap**
    - Pre: quiet
    - Effect: present
  - **Carry**
    - Pre: garb
    - Effect: garb \(\land\) clean
  - **Dolly**
    - Pre: garb
    - Effect: garb \(\land\) quiet
Extensions

- Lots of time optimizations
- Disjunctive preconditions
- Universally quantified (sort of) preconditions and effects
- Conditional planning