Planning Graphs

Slides from

https://cw.fel.cvut.cz/old/_media/courses/a4m33pah/cv10-graphplan.pdf

Planning Graphs

- Planning graphs are an efficient way to create a representation of a planning problem that can be used to
  - Achieve better heuristic estimates
  - Directly construct plans
- Planning graphs only work for propositional problems.

Planning Graphs

- Planning graphs consists of a seq of levels that correspond to time steps in the plan.
  - Level 0 is the initial state.
  - Each level consists of a set of literals and a set of actions that represent what *might be* possible at that step in the plan
  - *Might be* is the key to efficiency
  - Records only a restricted subset of possible negative interactions among actions.

Planning Graphs

- Each level consists of
- *Literals* = all those that *could* be true at that time step, depending upon the actions executed at preceding time steps.
- *Actions* = all those actions that *could* have their preconditions satisfied at that time step, depending on which of the literals actually hold.

PG Example

Init(Have(Cake))

Goal(Have(Cake) $\wedge$ Eaten(Cake))

Action(Eat(Cake),
  PRECOND: Have(Cake)
  EFFECT: $\neg$Have(Cake) $\wedge$ Eaten(Cake))

Action(Bake(Cake),
  PRECOND: $\neg$ Have(Cake)
  EFFECT: Have(Cake))

PG Example

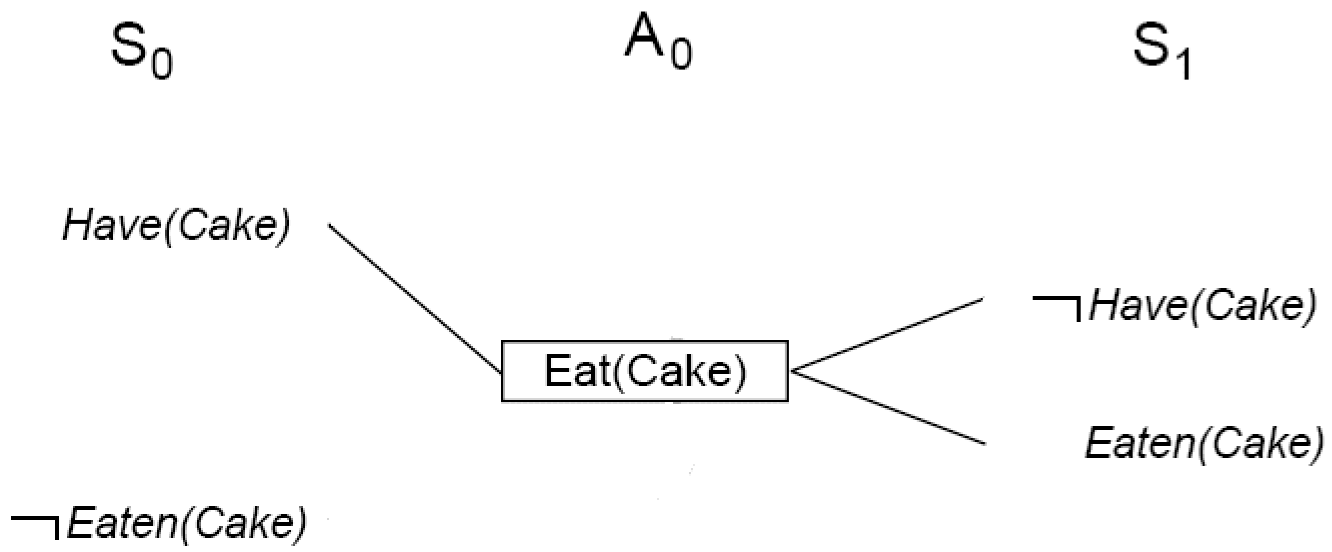
S_0 A_0 S_1

Have(Cake)

¬*Eaten(Cake)*

Create level 0 from initial problem state.

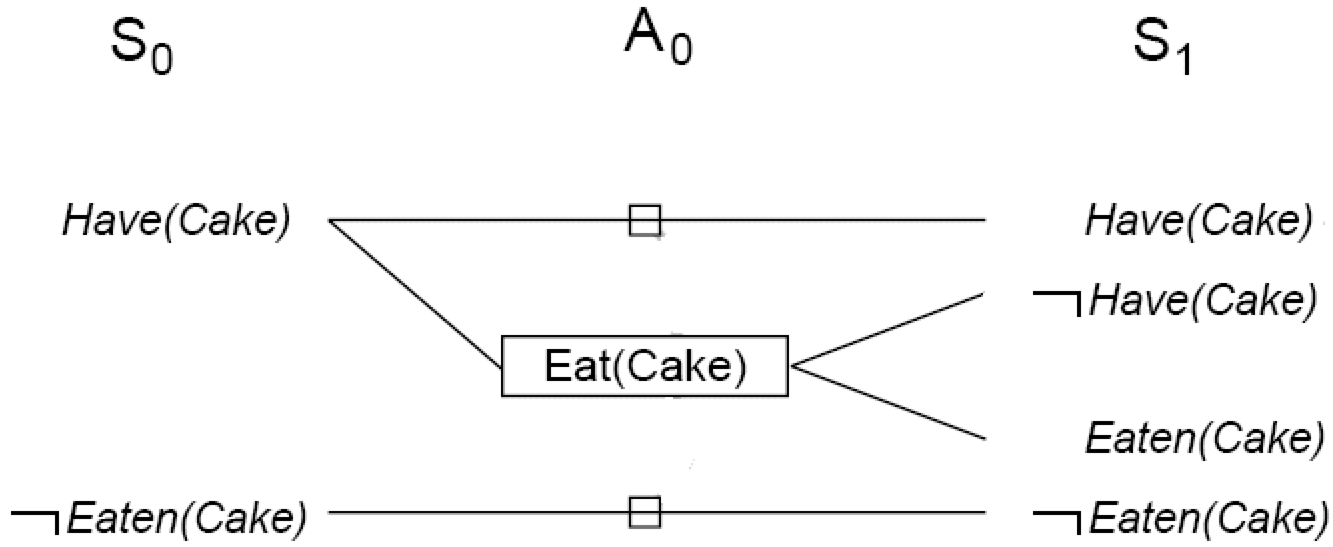
PG Example



Add all applicable actions.

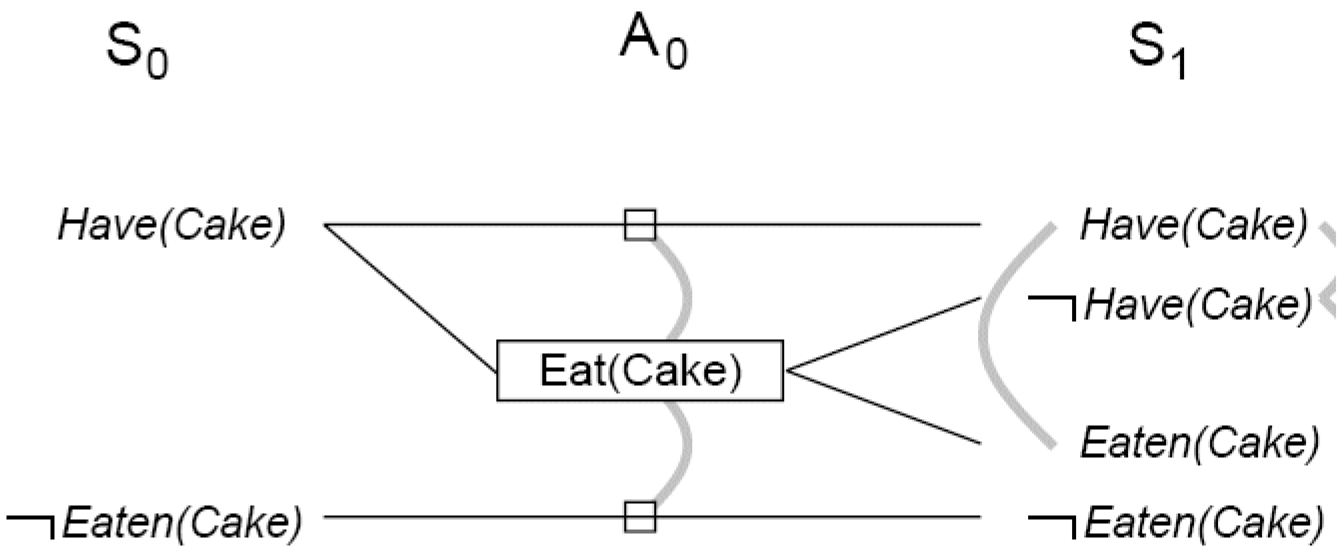
Add all effects to the next state.

PG Example



Add *persistence actions* (inaction = no-ops) to map all literals in state S_i to state S_{i+1}.

PG Example

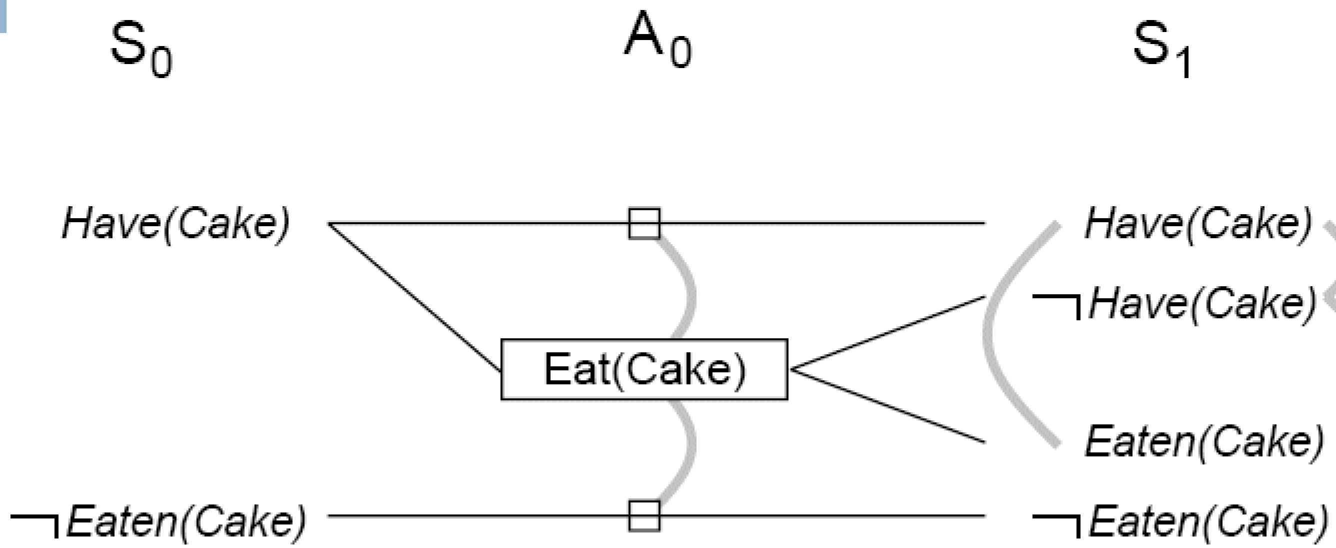


Identify *mutual exclusions* between actions and literals based on potential conflicts.

Mutual exclusion

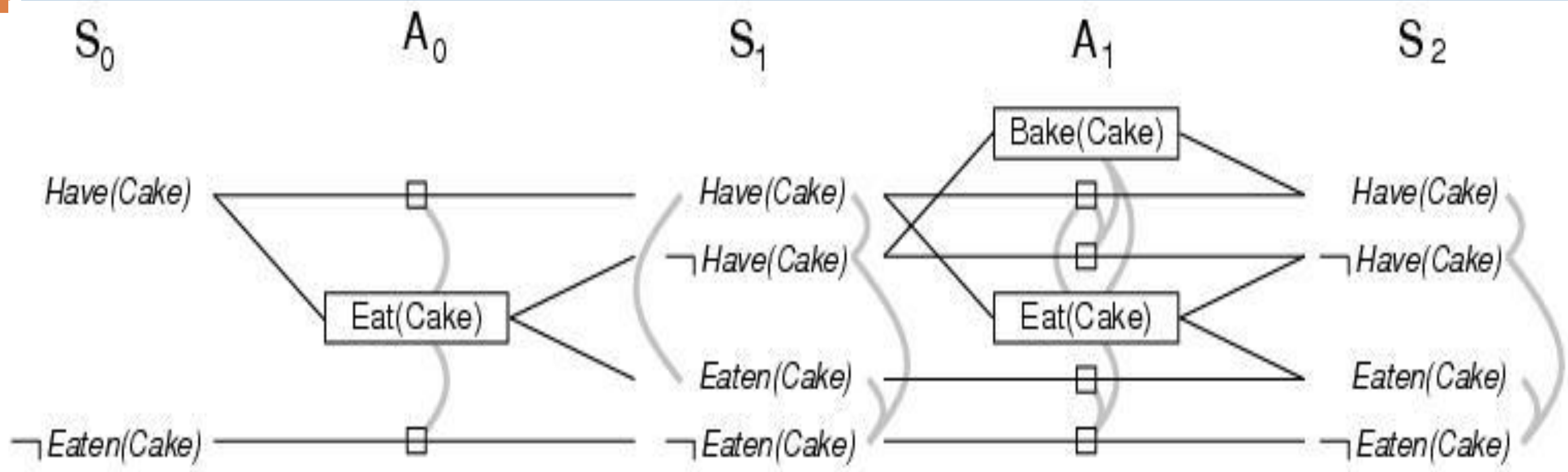
- A mutex relation holds between **two actions** when:
  - *Inconsistent effects*: one action negates the effect of another.
  - *Interference*: one of the effects of one action is the negation of a precondition of the other.
  - *Competing needs*: one of the preconditions of one action is mutually exclusive with the precondition of the other.
- A mutex relation holds between **two literals** when:
  - one is the negation of the other OR
  - each possible action pair that could achieve the literals is mutex (inconsistent support).

Cake example



- Level S_1 contains all literals that could result from picking any subset of actions in A_0
  - Conflicts between literals that can not occur together (as a consequence of the selection action) are represented by mutex links.
  - S1 defines multiple states and the mutex links are the constraints that define this set of states.

Cake example



- Repeat process until graph levels off:
  - two consecutive levels are identical, or
  - contain the same amount of literals (explanation follows later)

The GRAPHPLAN Algorithm

- Extract a solution directly from the PG

function GRAPHPLAN(*problem*) **return** *solution* or failure
    graph ← INITIAL-PLANNING-GRAPH(*problem*)
    goals ← GOALS[*problem*]
    loop do
        if *goals* all non-mutex in last level of graph **then do**
            solution ← EXTRACT-SOLUTION(*graph, goals,* LENGTH(*graph*))
            if *solution* ≠ failure **then return** *solution*
            else if NO-SOLUTION-POSSIBLE(*graph*) **then return** failure
          graph ← EXPAND-GRAPH(*graph, problem*)

GRAPHPLAN Termination

- Termination? YES
- PG are monotonically increasing or decreasing:
  - Literals increase monotonically
  - Actions increase monotonically
  - Mutexes decrease monotonically
- Because of these properties and because there is a finite number of actions and literals, every PG will eventually level off