

**Idea:** search backwards from the goal description: nodes correspond to **subgoals**, and arcs to actions.

A **subgoal** is an assignment of values to some features.

Search problem:

- Nodes are subgoals
- There is an arc  $\langle g, g' \rangle$  labeled with action  $A$  if
  - ▶  $A$  achieves one of the assignments in  $g$
  - ▶  $g'$  is a proposition that must be true immediately before action  $A$  so that  $g$  is true immediately after.
- The start node is the goal to be achieved.
- $goal(g)$  is true if  $g$  is a proposition that is true of the initial state.

# Defining nodes and arcs

- A node  $g$  can be represented as a set of assignments of values to variables:

$$[X_1 = v_1, \dots, X_n = v_n]$$

This is a set of assignments you want to hold.

- The last action achieves one of the  $X_i = v_i$ , and does not achieve  $X_j = v'_j$  where  $v'_j$  is different to  $v_j$ .
- The neighbor of  $g$  along arc  $A$  must contain:
  - ▶ The prerequisites of action  $A$
  - ▶ All of the elements of  $g$  that were not achieved by  $A$

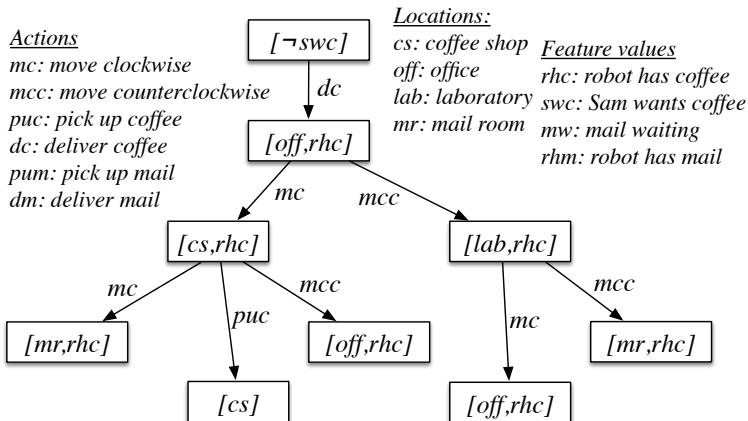
it must be **consistent** = have at most one value for each feature.

# Formalizing arcs using STRIPS notation

$\langle g, g' \rangle$  is an arc labeled with action  $A$  where  $g$  is  $[X_1 = v_1, \dots, X_n = v_n]$  and  $A$  is an action, if

- $\exists i X_i = v_i$  is on the effects list of action  $A$
- $\forall j X_j = v'_j$  is not on the effects list for  $A$ , where  $v'_j \neq v_j$
- $g' = \text{preconditions}(A) \cup \{X_k = v_k \in g : X_k = v_k \notin \text{effects}(A)\}$   
if it is consistent

# Regression example



## Loop detection and multiple-path pruning

- Goal  $G_1$  is simpler than goal  $G_2$  if  $G_1$  is a subset of  $G_2$ .
  - ▶ It is easier to solve  $[cs]$  than  $[cs, rhc]$ .
- If you have a path to node  $N$  have already found a path to a *simpler* goal, you can prune the path  $N$ .

- You can define a heuristic function that estimates how difficult it is to solve a goal from a state.  
A heuristic function defined the cost of getting from a state to a (sub)goal. This is the same as a heuristic for the forward planner.
- You can use domain-specific knowledge to remove impossible goals, e.g.
  - ▶ It is often not obvious from an action description to conclude whether an agent can hold multiple items at any time.

# Comparing forward and regression planners

- Which is more efficient depends on:
  - ▶ The branching factor
  - ▶ How good the heuristics are
- Forward planning is unconstrained by the goal (except as a source of heuristics).
- Regression planning is unconstrained by the initial state (except as a source of heuristics)

