

PLANNING

CHAPTER 11

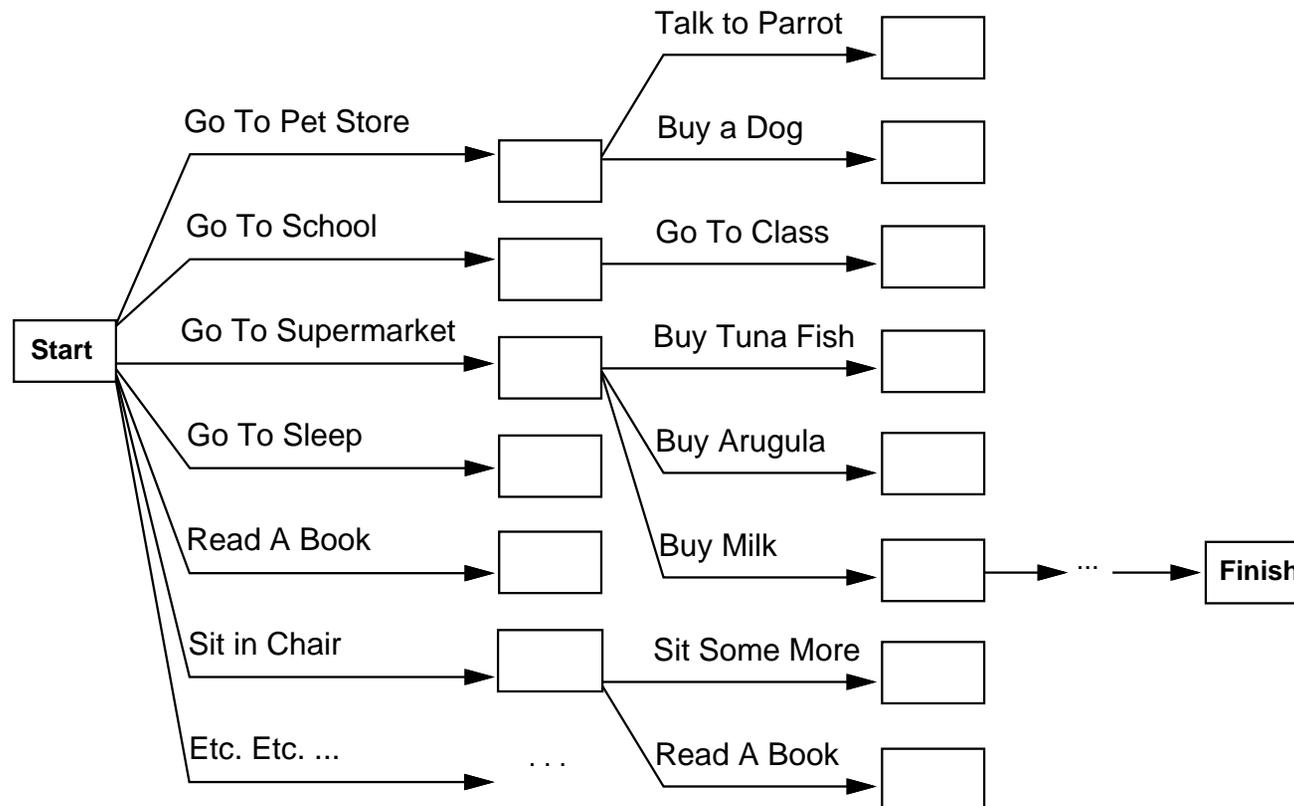
Outline

- ◇ Search vs. planning
- ◇ STRIPS operators
- ◇ Partial-order planning

Search vs. planning

Consider the task *get milk, bananas, and a cordless drill*

Standard search algorithms seem to fail miserably:



After-the-fact heuristic/goal test inadequate

Search vs. planning contd.

Planning systems do the following:

- 1) open up action and goal representation to allow selection
- 2) divide-and-conquer by subgoaling
- 3) relax requirement for sequential construction of solutions

	Search	Planning
States	Lisp data structures	Logical sentences
Actions	Lisp code	Preconditions/outcomes
Goal	Lisp code	Logical sentence (conjunction)
Plan	Sequence from S_0	Constraints on actions

STRIPS operators

Tidily arranged actions descriptions, restricted language

ACTION: $Buy(x)$

PRECONDITION: $At(p), Sells(p, x)$

EFFECT: $Have(x)$

[Note: this abstracts away many important details!]

Restricted language \Rightarrow efficient algorithm

Precondition: conjunction of positive literals

Effect: conjunction of literals

A complete set of STRIPS operators can be translated into a set of successor-state axioms

$At(p) Sells(p, x)$

Buy(x)

$Have(x)$

Partially ordered plans

Partially ordered collection of steps with

Start step has the initial state description as its effect

Finish step has the goal description as its precondition

causal links from outcome of one step to precondition of another
temporal ordering between pairs of steps

Open condition = precondition of a step not yet causally linked

A plan is complete iff every precondition is achieved

A precondition is achieved iff it is the effect of an earlier step
and no possibly intervening step undoes it

Example

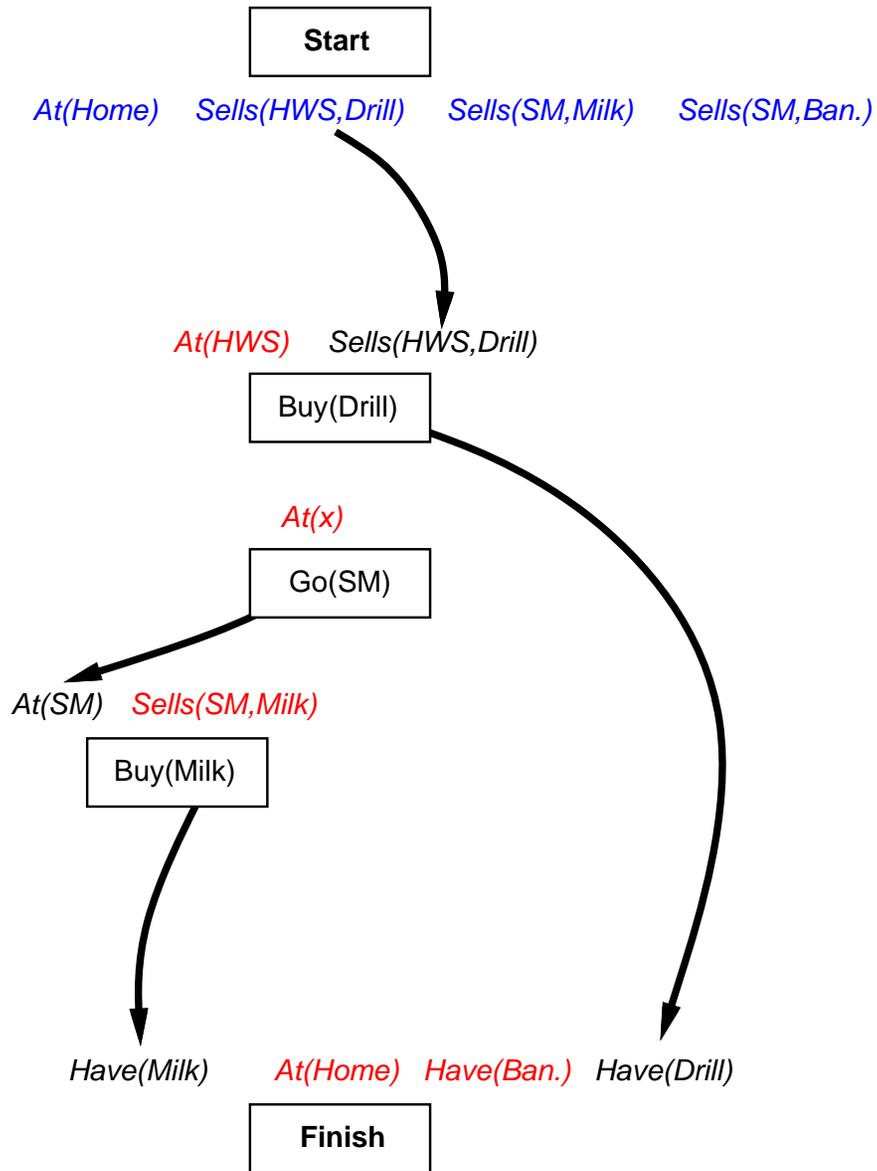
Start

At(Home) Sells(HWS,Drill) Sells(SM,Milk) Sells(SM,Ban.)

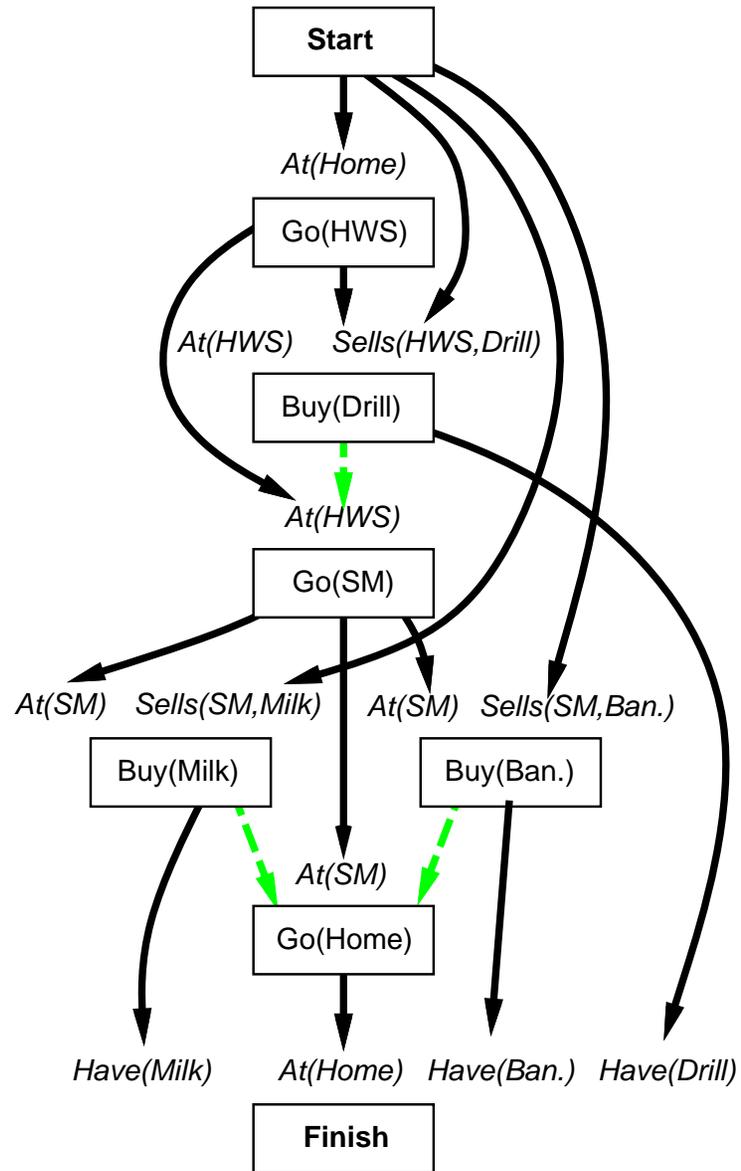
Have(Milk) At(Home) Have(Ban.) Have(Drill)

Finish

Example



Example



Planning process

Operators on partial plans:

add a **link** from an existing action to an open condition

add a **step** to fulfill an open condition

order one step wrt another to remove possible conflicts

Gradually move from incomplete/vague plans to complete, correct plans

Backtrack if an open condition is unachievable or
if a conflict is unresolvable

POP algorithm sketch

function POP(*initial*, *goal*, *operators*) **returns** *plan*

plan ← MAKE-MINIMAL-PLAN(*initial*, *goal*)

loop do

if SOLUTION?(*plan*) **then return** *plan*

S_{need}, c ← SELECT-SUBGOAL(*plan*)

 CHOOSE-OPERATOR(*plan*, *operators*, S_{need}, c)

 RESOLVE-THREATS(*plan*)

end

function SELECT-SUBGOAL(*plan*) **returns** S_{need}, c

 pick a plan step S_{need} from STEPS(*plan*)

 with a precondition c that has not been achieved

return S_{need}, c

POP algorithm contd.

procedure CHOOSE-OPERATOR($plan, operators, S_{need}, c$)

choose a step S_{add} from $operators$ or STEPS($plan$) that has c as an effect

if there is no such step **then fail**

add the causal link $S_{add} \xrightarrow{c} S_{need}$ to LINKS($plan$)

add the ordering constraint $S_{add} \prec S_{need}$ to ORDERINGS($plan$)

if S_{add} is a newly added step from $operators$ **then**

add S_{add} to STEPS($plan$)

add $Start \prec S_{add} \prec Finish$ to ORDERINGS($plan$)

procedure RESOLVE-THREATS($plan$)

for each S_{threat} that threatens a link $S_i \xrightarrow{c} S_j$ in LINKS($plan$) **do**

choose either

Demotion: Add $S_{threat} \prec S_i$ to ORDERINGS($plan$)

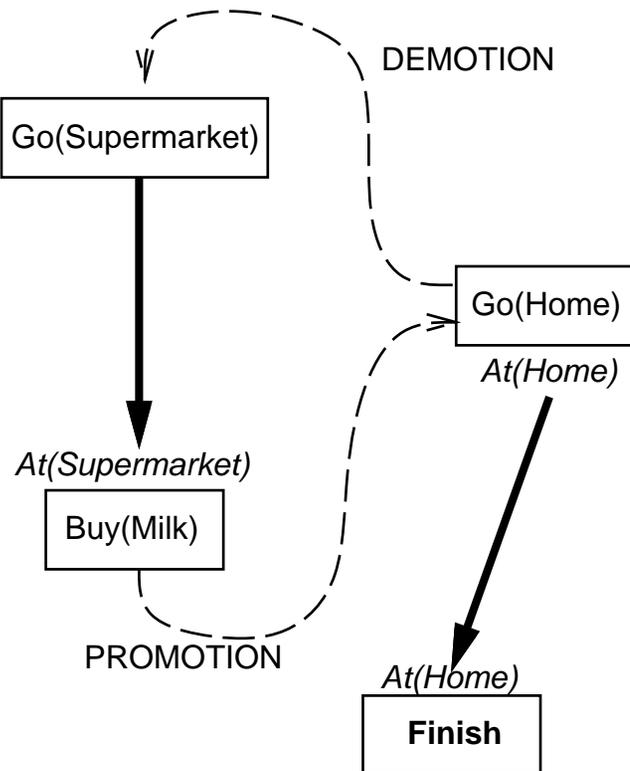
Promotion: Add $S_j \prec S_{threat}$ to ORDERINGS($plan$)

if not CONSISTENT($plan$) **then fail**

end

Clobbering and promotion/demotion

A **clobberer** is a potentially intervening step that destroys the condition achieved by a causal link. E.g., $Go(Home)$ clobbers $At(Supermarket)$:



Demotion: put before $Go(Supermarket)$

Promotion: put after $Buy(Milk)$

Properties of POP

Nondeterministic algorithm: backtracks at **choice** points on failure:

- choice of S_{add} to achieve S_{need}
- choice of demotion or promotion for clobberer
- selection of S_{need} is irrevocable

POP is sound, complete, and **systematic** (no repetition)

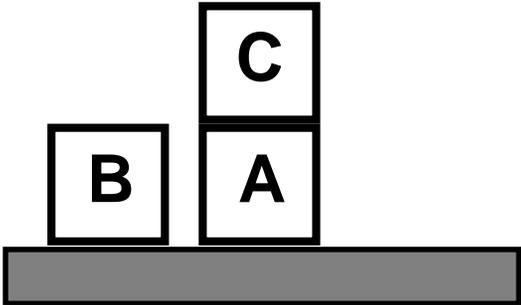
Extensions for disjunction, universals, negation, conditionals

Can be made efficient with good heuristics derived from problem description

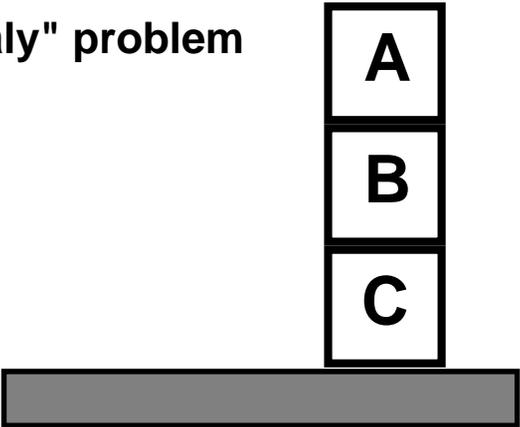
Particularly good for problems with many loosely related subgoals

Example: Blocks world

"Sussman anomaly" problem



Start State



Goal State

Clear(x) On(x,z) Clear(y)

PutOn(x,y)

*~On(x,z) ~Clear(y)
Clear(z) On(x,y)*

Clear(x) On(x,z)

PutOnTable(x)

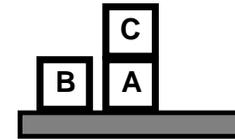
~On(x,z) Clear(z) On(x,Table)

+ several inequality constraints

Example contd.

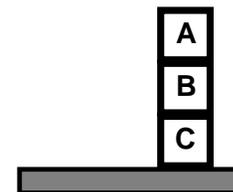
START

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

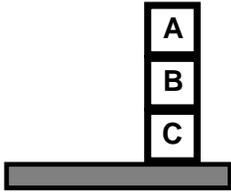
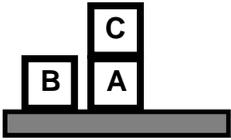
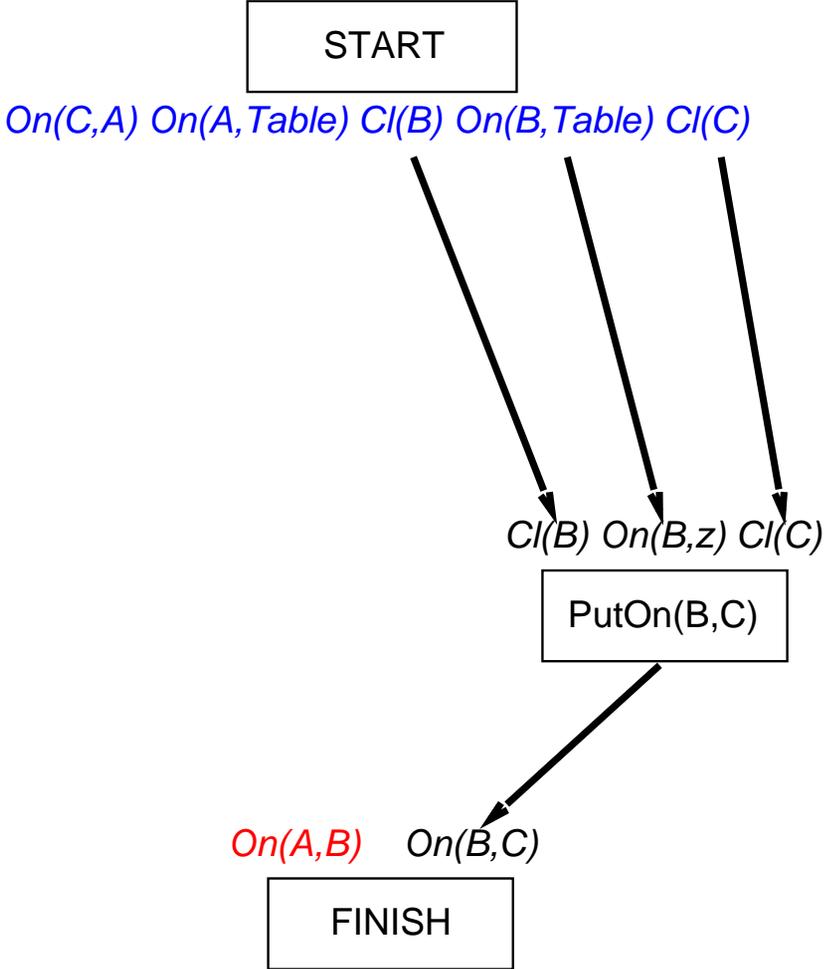


On(A,B) On(B,C)

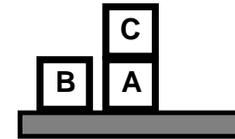
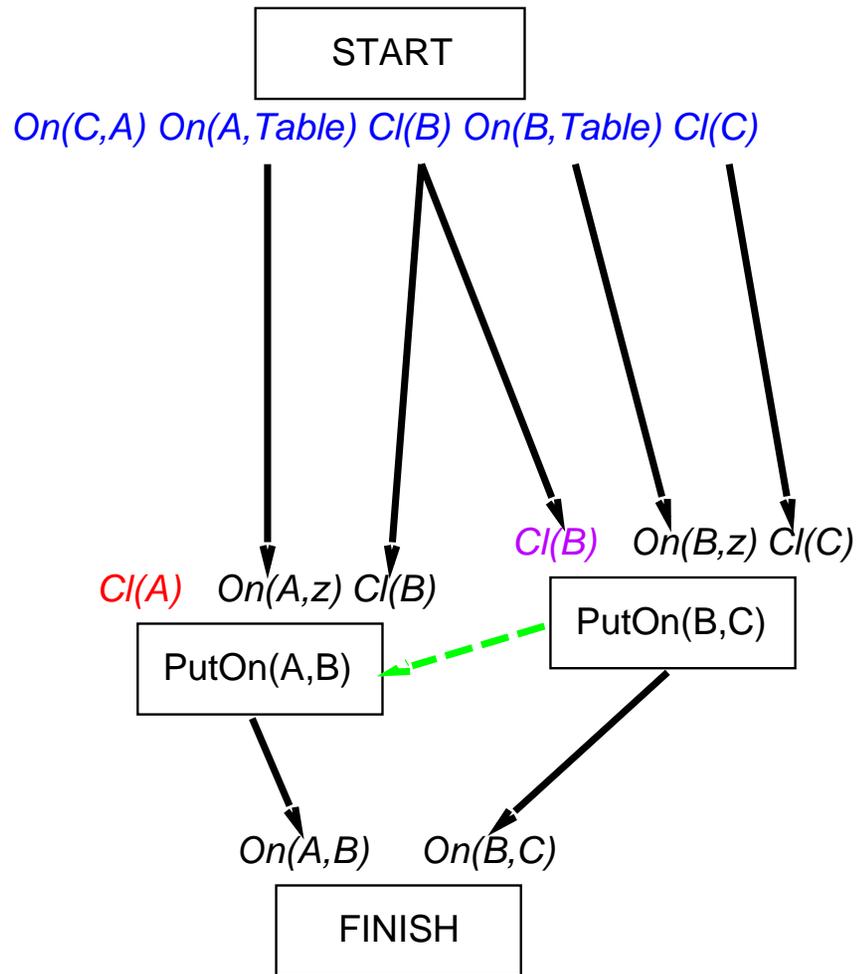
FINISH



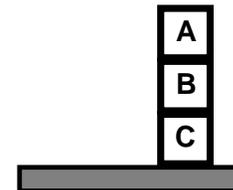
Example contd.



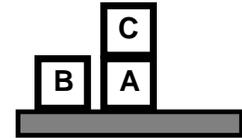
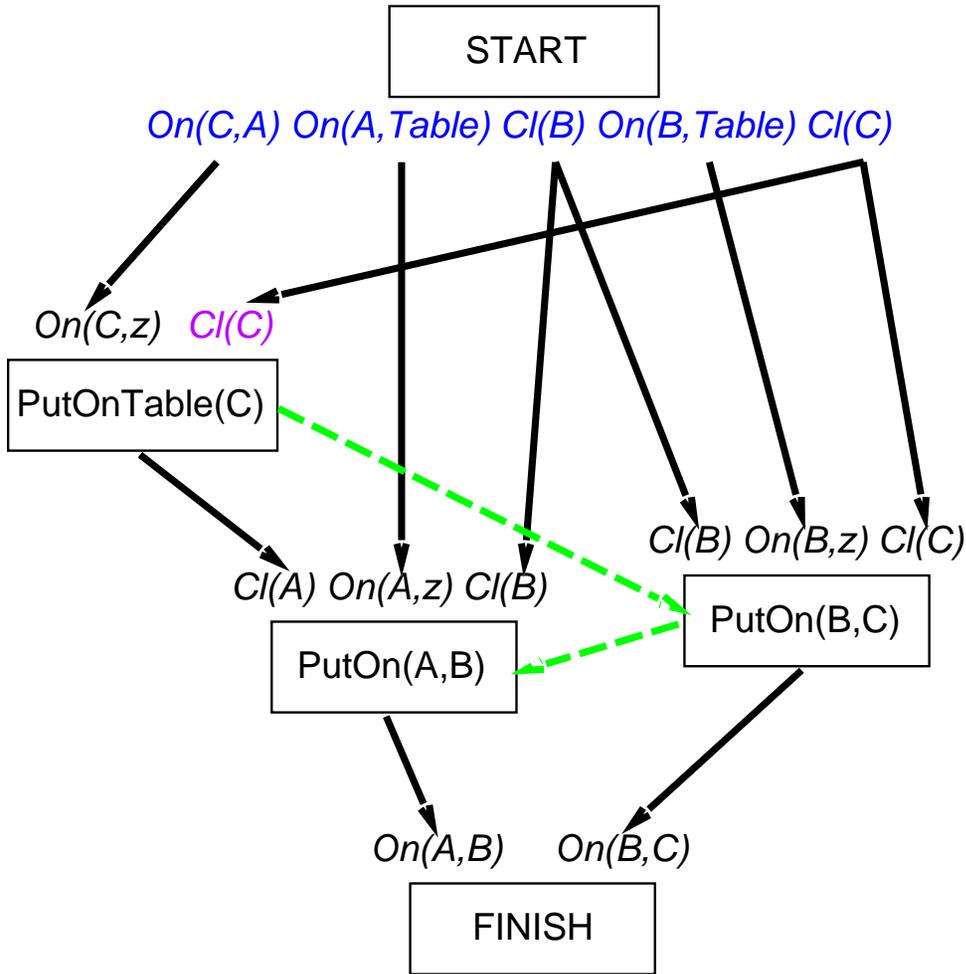
Example contd.



PutOn(A,B)
 clobbers Cl(B)
 => order after
 PutOn(B,C)



Example contd.



PutOn(A,B)
 clobbers Cl(B)
 => order after
 PutOn(B,C)

PutOn(B,C)
 clobbers Cl(C)
 => order after
 PutOnTable(C)

