

Artificial Intelligence

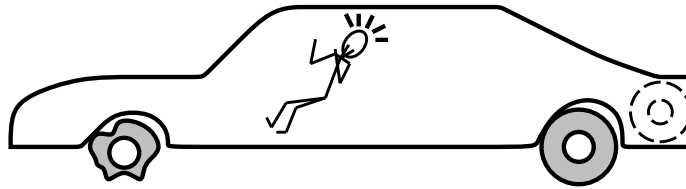
Topic 10

Planning and Acting

- ◇ The real world
- ◇ Conditional planning
- ◇ Monitoring and replanning
- ◇ Integrated planning and acting

Reading: Russell & Norvig, Chapter 13

1. The real world



START

*~Flat(Spare) Intact(Spare) Off(Spare)
On(Tire1) Flat(Tire1)*

On(x) ~Flat(x)

FINISH

On(x)

Remove(x)

Off(x) ClearHub

Off(x) ClearHub

Puton(x)

On(x) ~ClearHub

Intact(x) Flat(x)

Inflate(x)

~Flat(x)

1.1 Incomplete/incorrect information

Incomplete information

- Unknown preconditions, e.g., *Intact(Spare)*?
- Disjunctive effects, e.g., *Inflate(x)* causes *Inflated(x)* or *SlowHiss(x)* or *Burst(x)* or *BrokenPump* or ...

Incorrect information

- Current state incorrect, e.g., spare NOT intact
- Missing/incorrect postconditions in operators

“Qualification problem”

⇒ can never finish listing all the required preconditions and possible conditional outcomes of actions

1.2 Solutions

Conditional planning

- Plan to obtain information \Rightarrow *observation actions*
- Subplan for each contingency, e.g.,

[*Check(Tire1)*, **If** (*Intact(Tire1)*), [*Inflate(Tire1)*], [*CallRAC*])]

\Rightarrow Expensive because it plans for many unlikely cases

Monitoring/Replanning

\Rightarrow Unanticipated outcomes may lead to failure (e.g., no RAC card)

- Assume normal states, outcomes
- Check progress *during execution*, replan if necessary

In general, some monitoring is unavoidable

2. Conditional planning

[... , **If**(p , [*then plan*], [*else plan*]), ...]

Execution:

check p against current KB, execute “then” or “else”

Conditional planning: just like POP except

- if an open condition can be established by observation action
 - add the action to the plan
 - complete plan for each possible observation outcome
 - insert conditional step with these subplans

CheckTire(x)

KnowsIf(Intact(x))

2.1 Conditional planning example

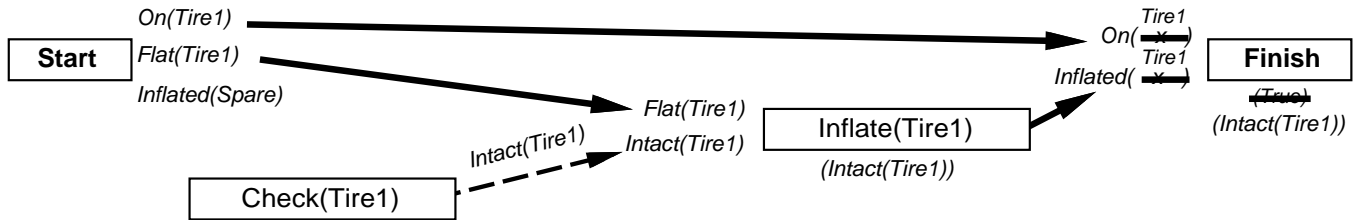
Start *On(Tire1)*
Flat(Tire1)
Inflated(Spare)

On(x) **Finish**
Inflated(x) *(True)*

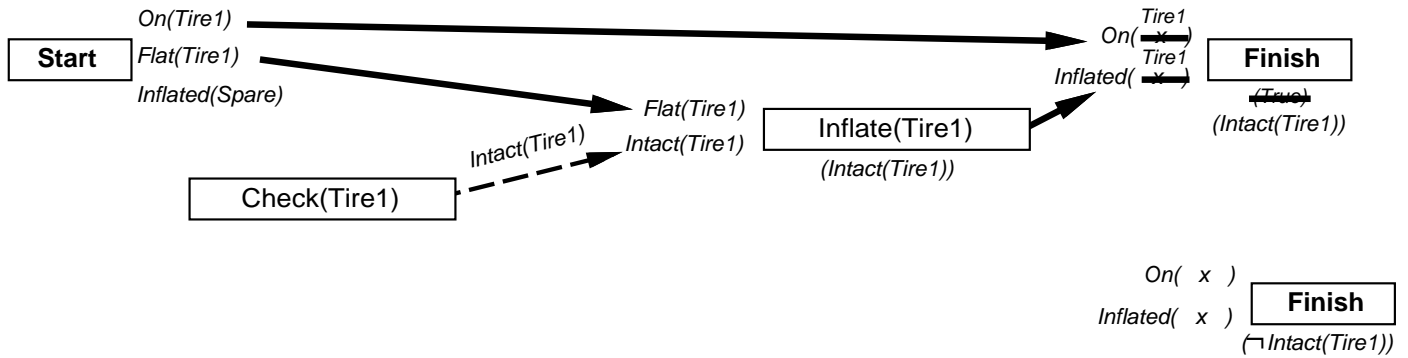
2.1 Conditional planning example



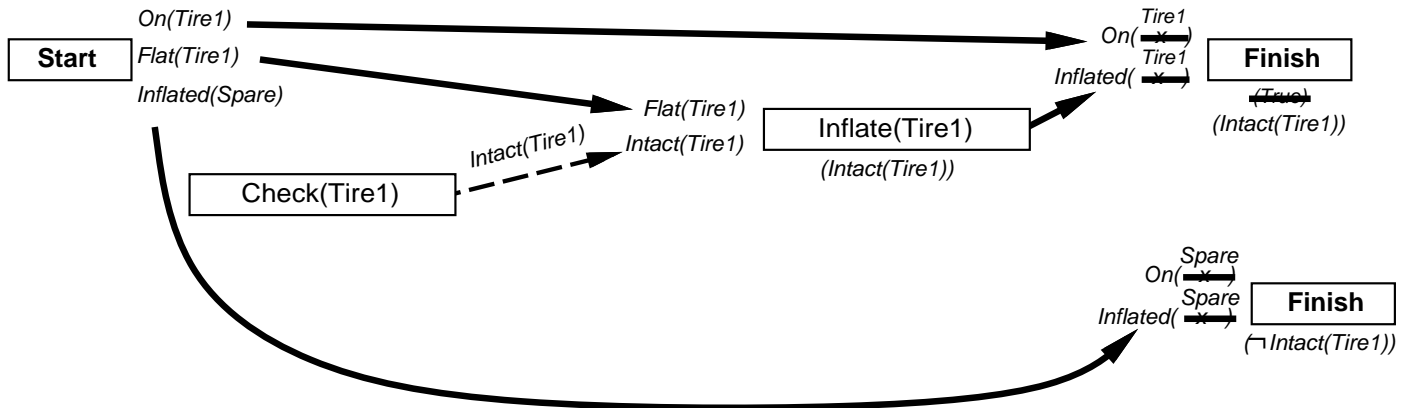
2.1 Conditional planning example



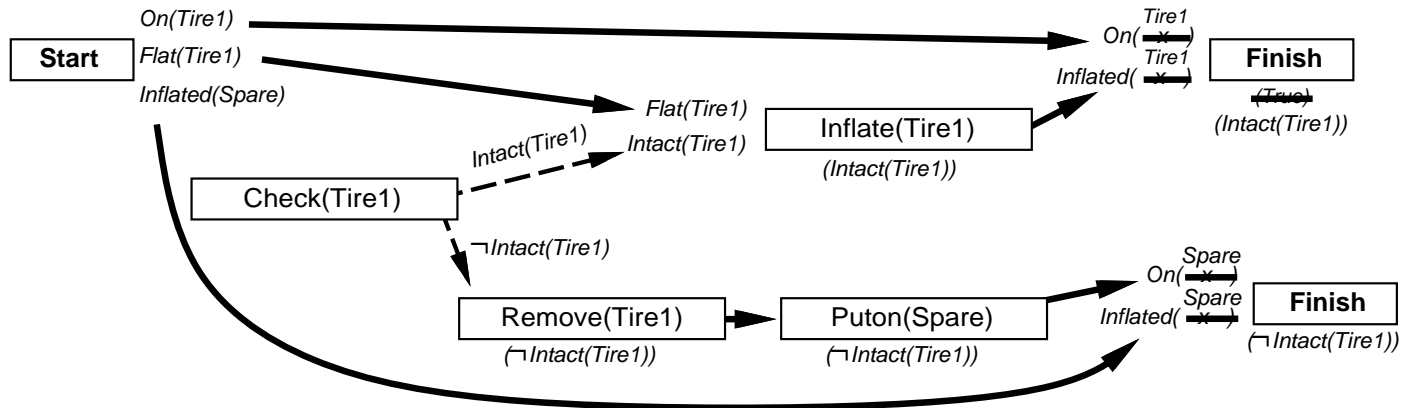
2.1 Conditional planning example



2.1 Conditional planning example



2.1 Conditional planning example



3. Monitoring

Execution monitoring

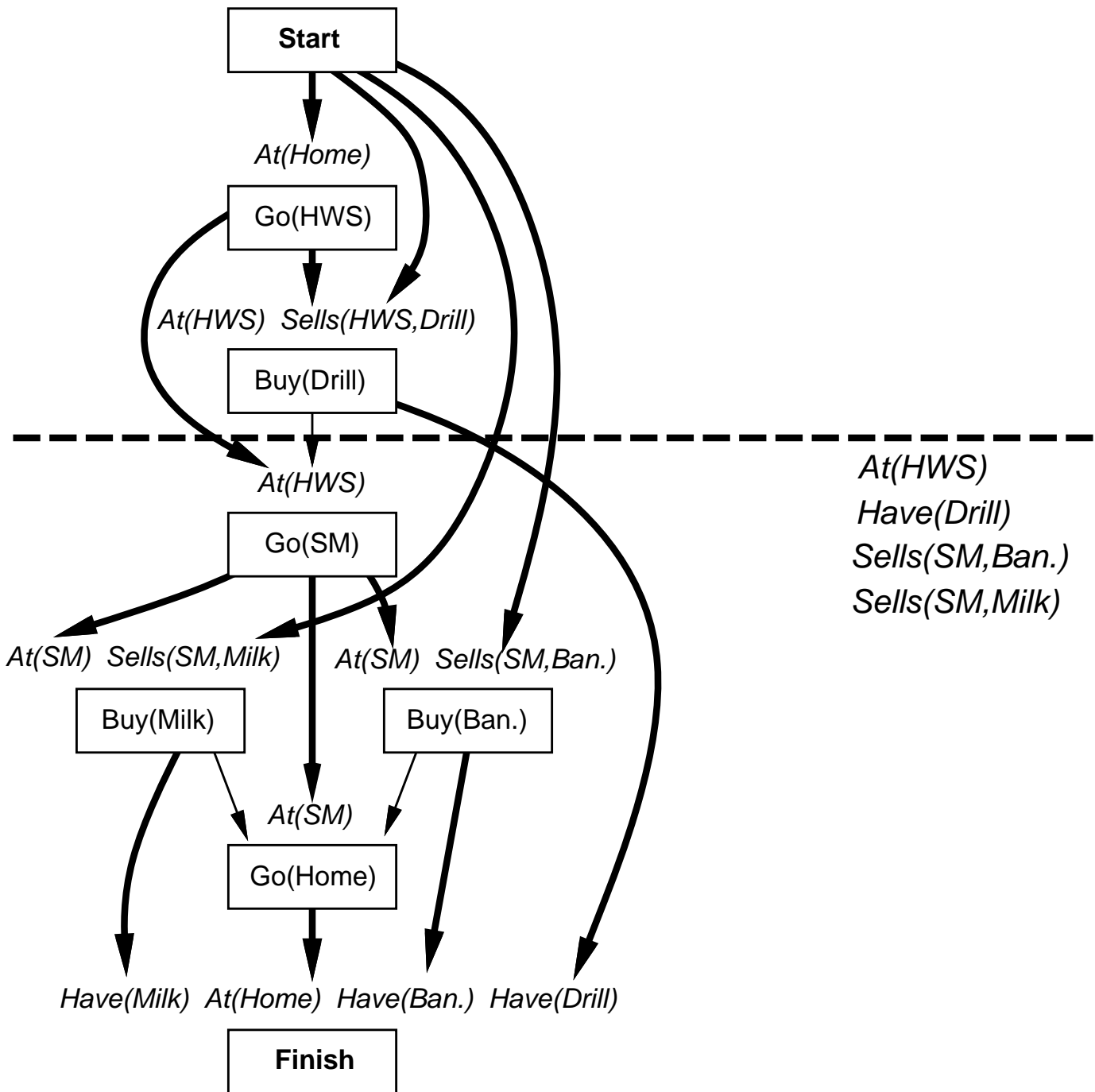
- “failure” = preconditions of *remaining plan* not met
- preconditions = causal links at current time

Action monitoring

- “failure” = preconditions of *next action* not met
(or action itself fails, e.g., robot bump sensor)

In both cases, need to *replan*

3.1 Preconditions for remaining plan

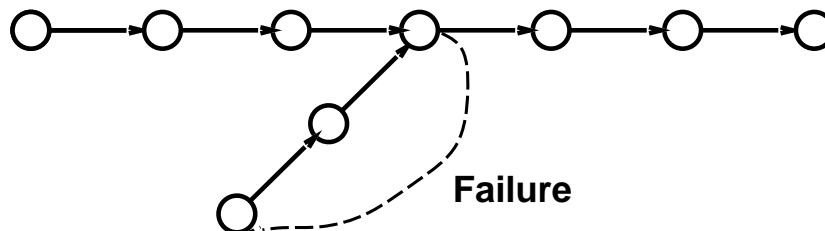


3.2 Replanning

Simplest: on failure, replan from scratch

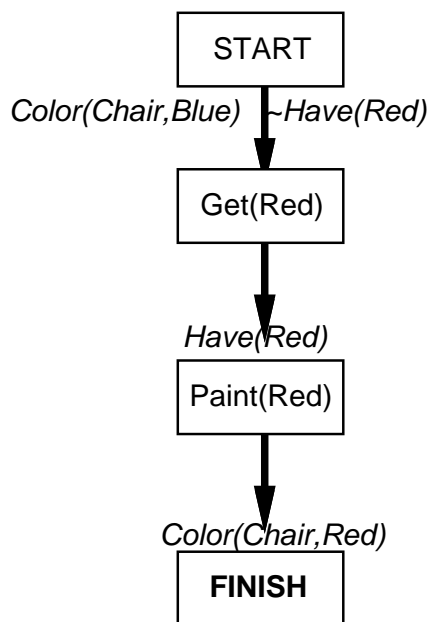
Better (but harder): plan to get back on track by reconnecting to best continuation

⇒ “loop until done” behavior (with no explicit loop)



PRECONDITIONS

FAILURE RESPONSE



none

N/A

Have(Red)

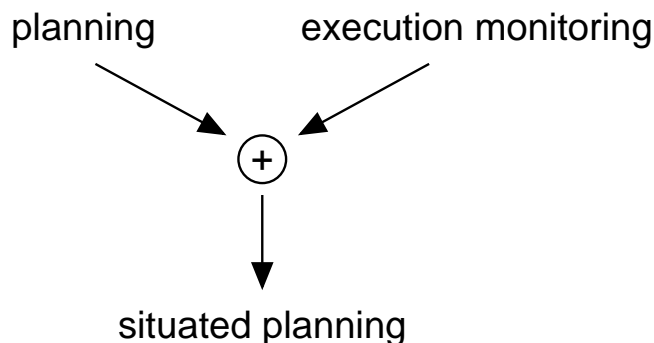
Fetch more red

Color(Chair,Red)

Repaint

4. Fully Integrated Planning and Acting

Instead of planning and execution monitoring as separate processes. . .

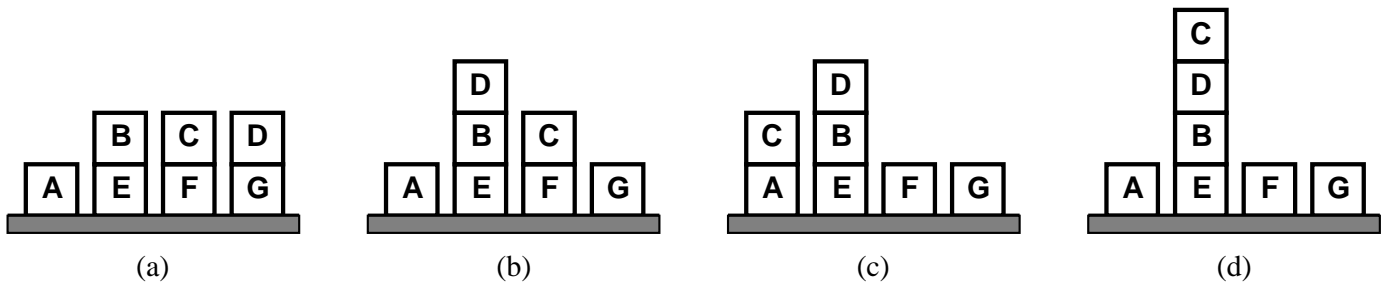


situated planning agent

- always “part of the way” through a plan
- activities include
 - execute a plan step
 - monitor the world
 - fix deficiencies in plan (open conditions, clobbering, etc)
 - refine plan in light of new information (execution errors, actions by other agents, etc)

4.1 Situated Planning Example

Agent wishes to achieve goal state $On(C,D), On(D,B)$



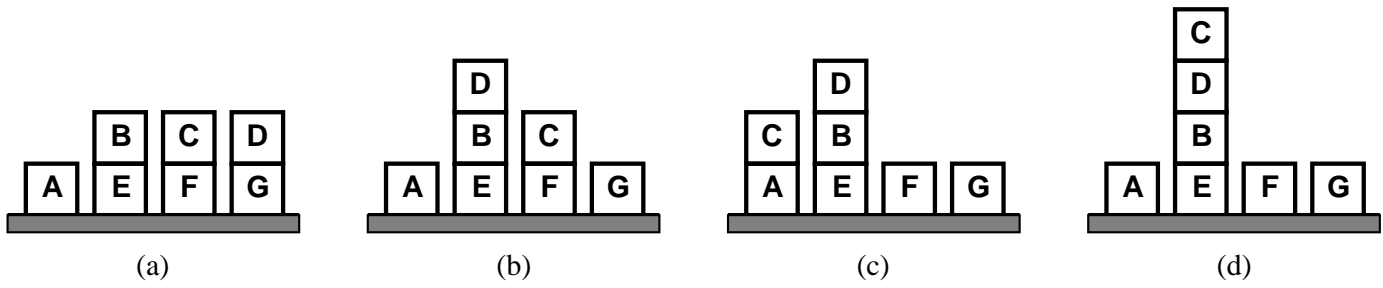
(a) start state

(b) another agent has put D on B

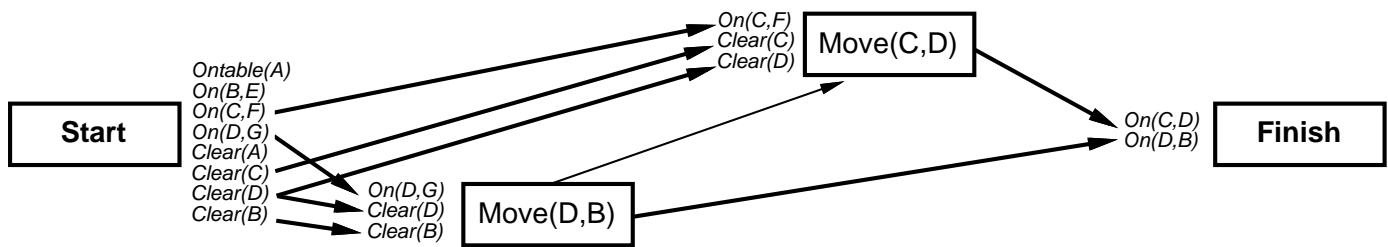
(c) our agent has executed $Move(C,D)$ but failed,
dropping C on A

(d) goal state achieved

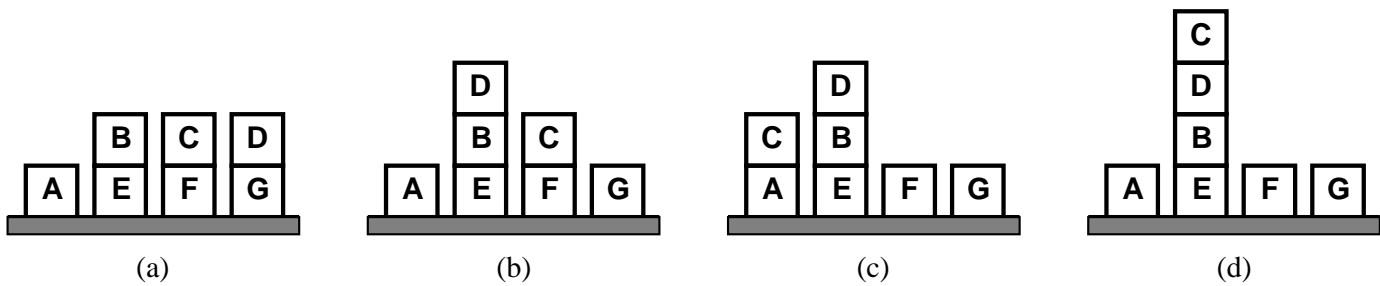
4.1 Situated Planning Example



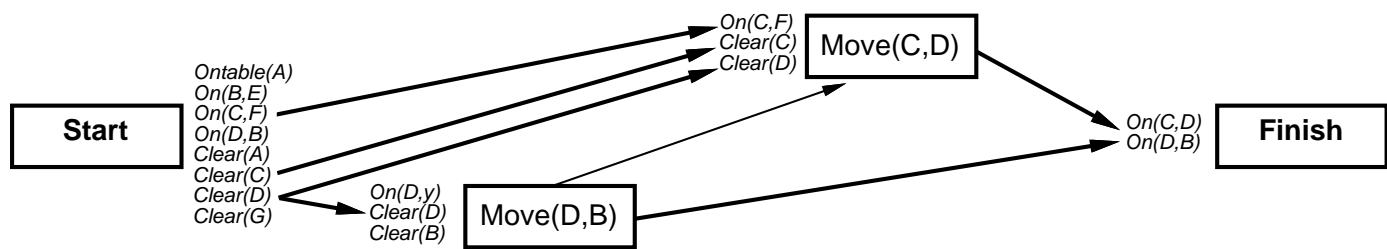
Initial plan (a).



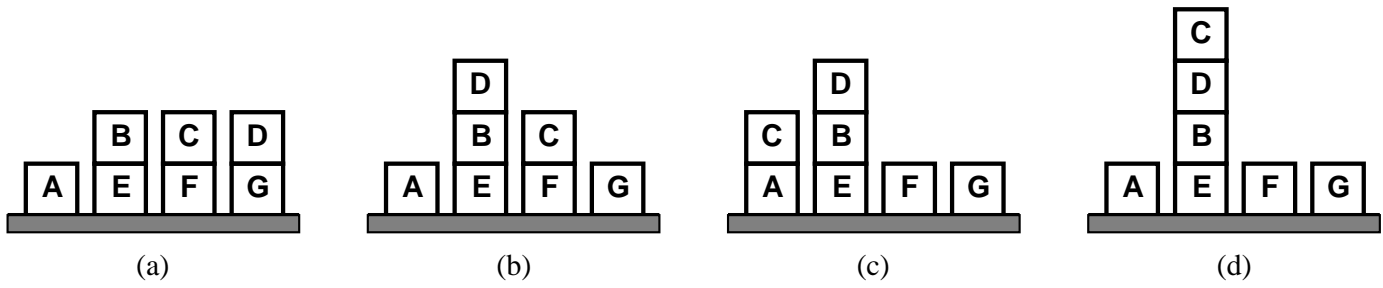
4.1 Situated Planning Example



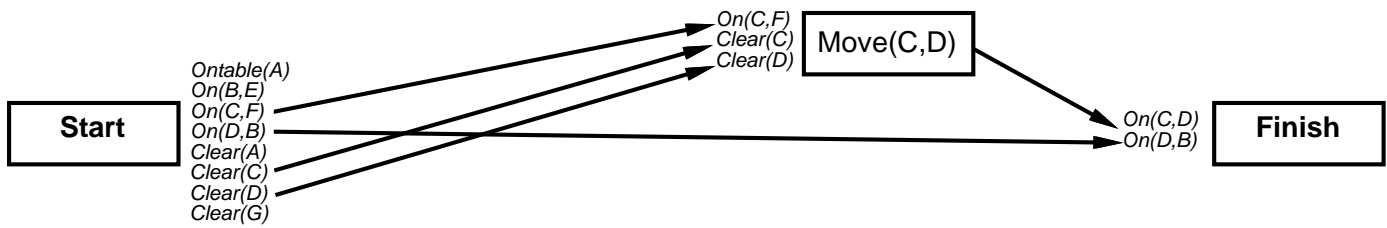
External agent changes environment (b).



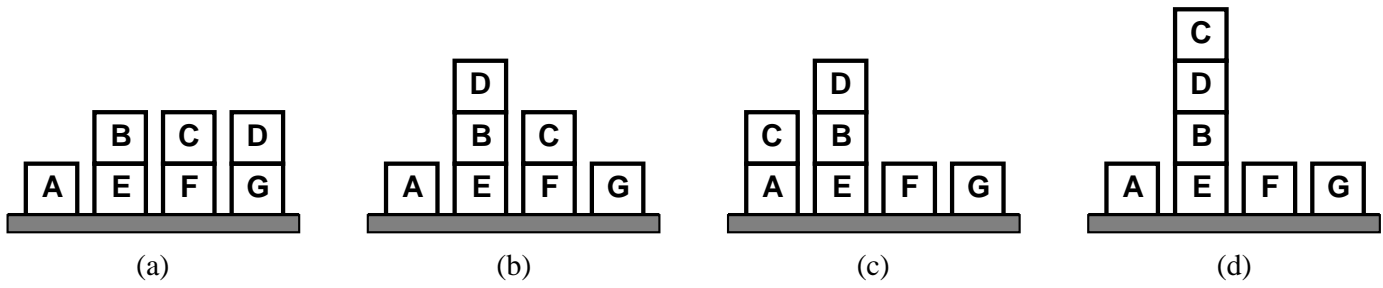
4.1 Situated Planning Example



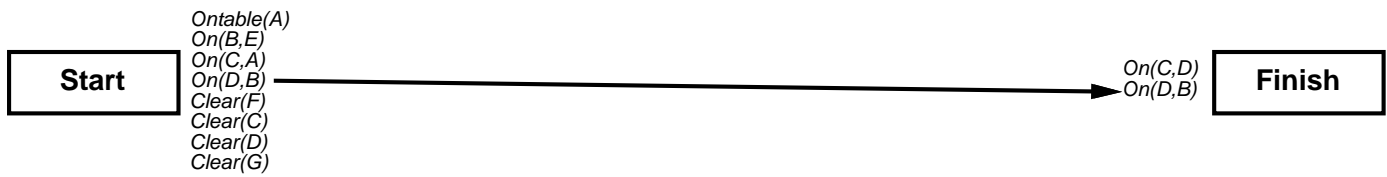
Redundant action removed.



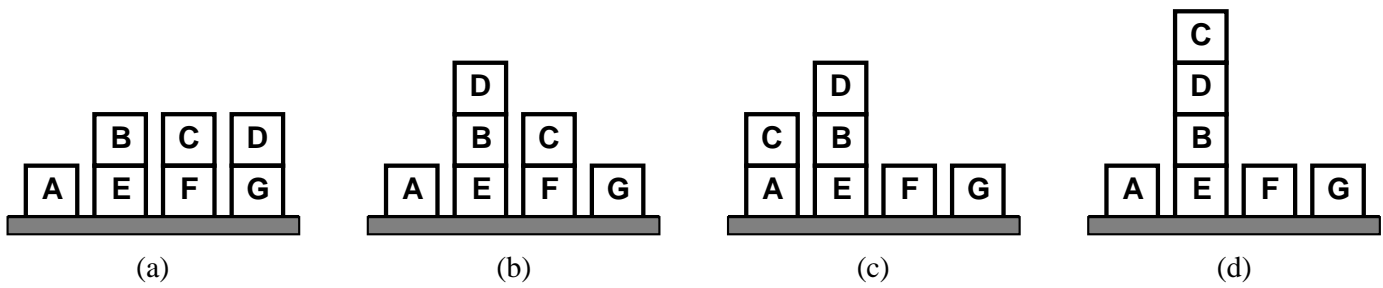
4.1 Situated Planning Example



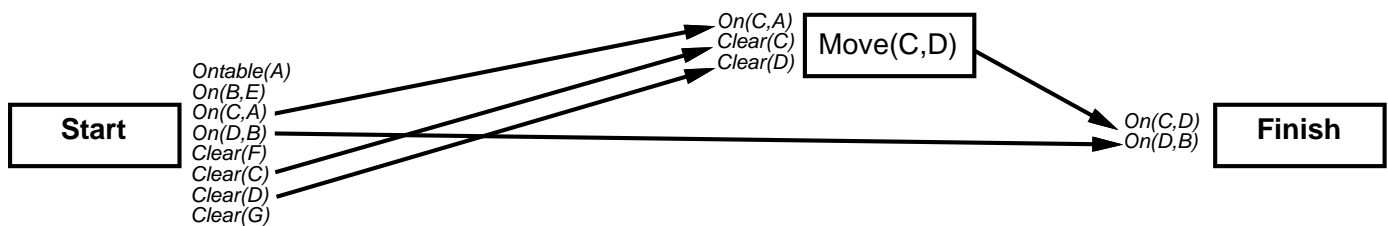
Move executed...



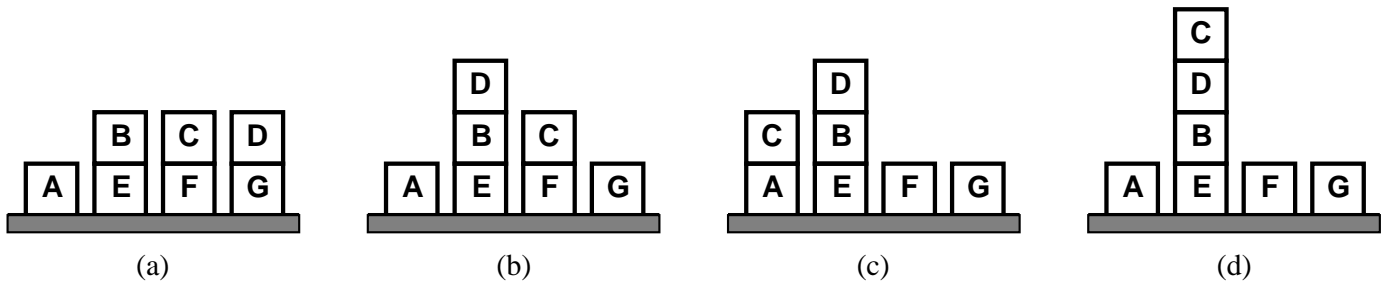
4.1 Situated Planning Example



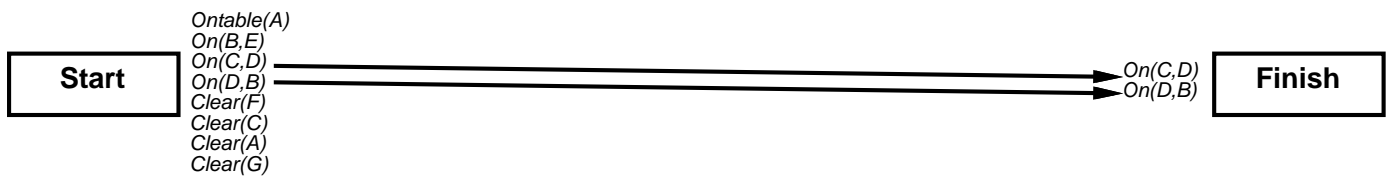
... but failed (c). Replan.



4.1 Situated Planning Example



Move executed and succeeded (d).



The End