

人工智能基础

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CH11. PLANNING AND ACTING IN REAL WORLD

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Outline

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



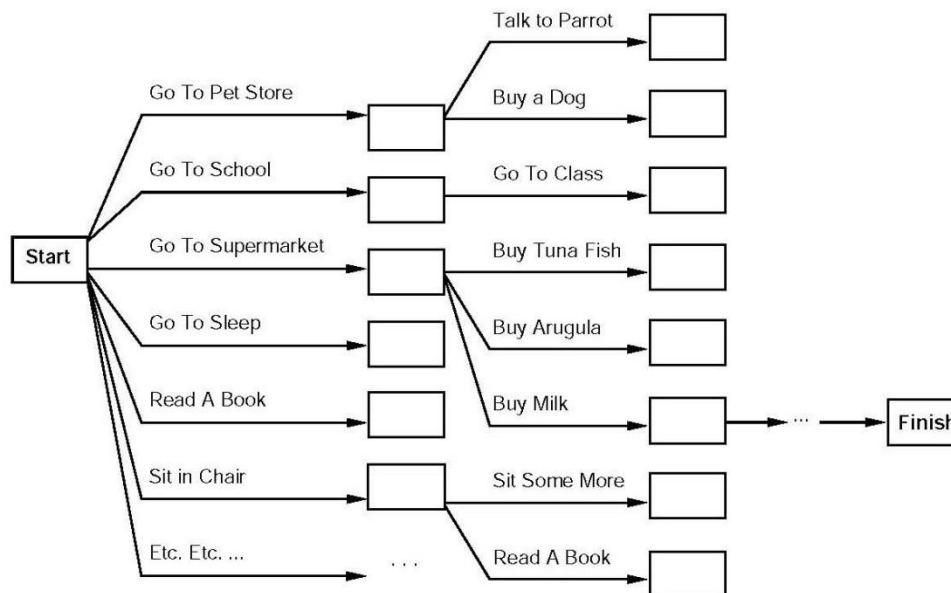


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Search vs. planning

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

Standard search algorithms seem to fail miserably:



After-the-fact heuristic/goal test inadequate



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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



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Planning in situation calculus

$PlanResult(p, s)$ is the situation resulting from executing p in s

$$PlanResult([], s) = s$$

$$PlanResult([a|p], s) = PlanResult(p, Result(a, s))$$

Initial state $At(Home, S_0) \wedge \neg Have(Milk, S_0) \wedge \dots$

Actions as Successor State axioms

$$Have(Milk, Result(a, s)) \Leftrightarrow$$

$$[(a = Buy(Milk) \wedge At(Supermarket, s)) \vee (Have(Milk, s) \wedge a \neq \dots)]$$

Query

$$s = PlanResult(p, S_0) \wedge At(Home, s) \wedge Have(Milk, s) \wedge \dots$$

Solution

$$p = [Go(Supermarket), Buy(Milk), Buy(Bananas), Go(HWS), \dots]$$

Principal difficulty: unconstrained branching, hard to apply heuristics



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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

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

$Buy(x)$

$Have(x)$



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State space vs. plan space

Standard search: node = concrete world state

Planning search: node = partial plan

Defn: open condition is a precondition of a step not yet fulfilled

Operators on partial plans:

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

- add a step to fulfill an open condition

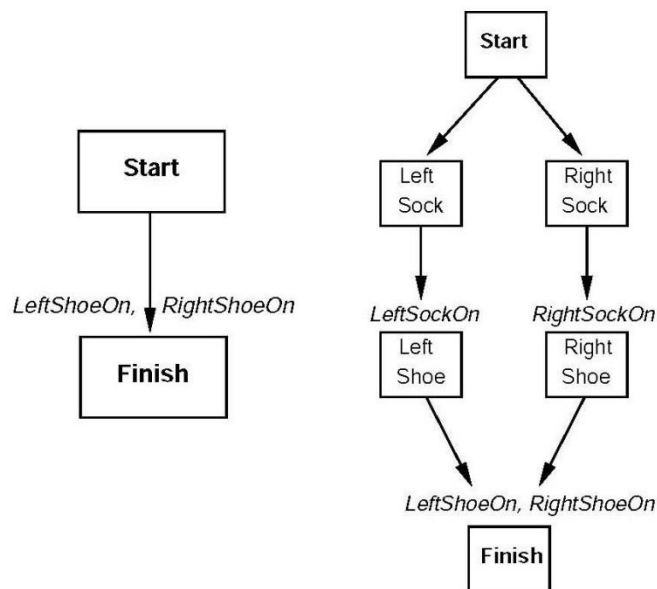
- order one step wrt another

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



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Partially ordered plans



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



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POP algorithm sketch

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

plan \leftarrow MAKE-MINIMAL-PLAN(*initial*, *goal*)

loop do

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

$S_{need}, c \leftarrow$ 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*)

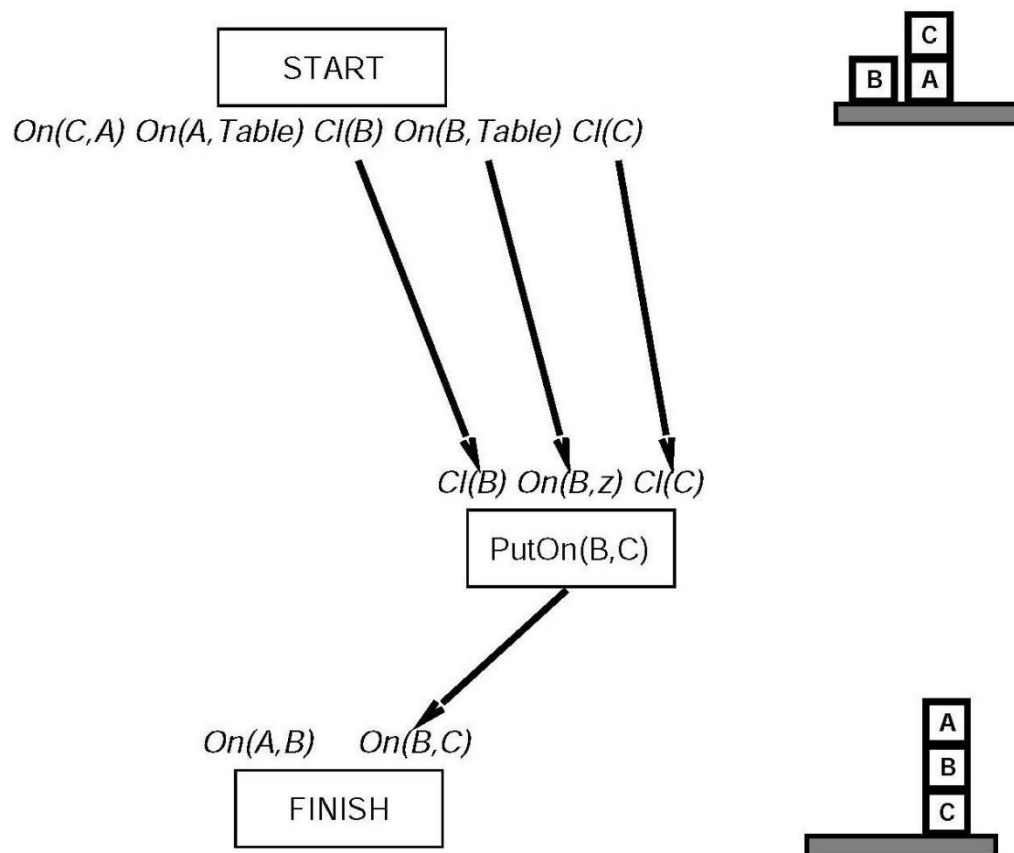
 with a precondition *c* that has not been achieved

return S_{need}, c



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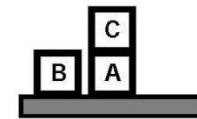
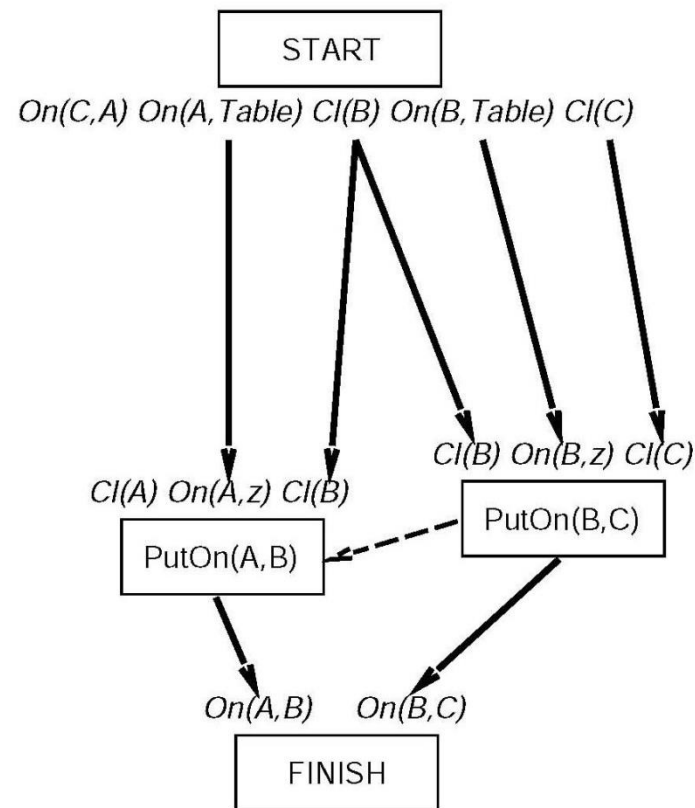
Example contd.



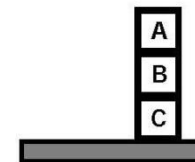


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Example contd.



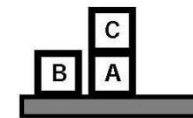
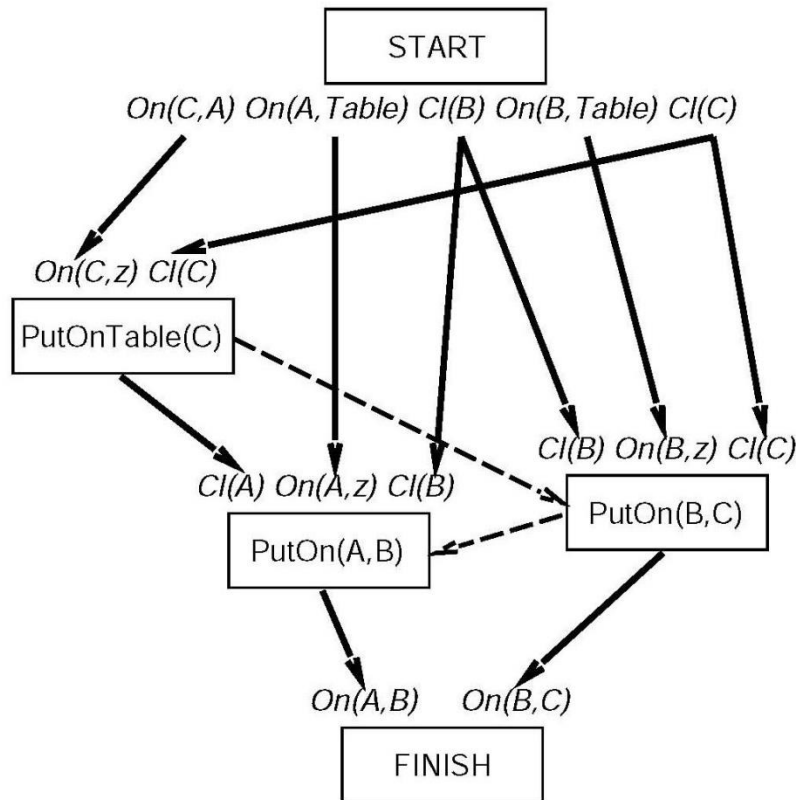
PutOn(A,B)
clobbers Cl(B)
=> order after
PutOn(B,C)





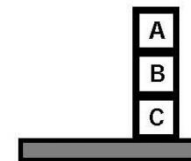
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Example contd.



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

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





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Example contd.

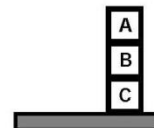
START

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



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

FINISH



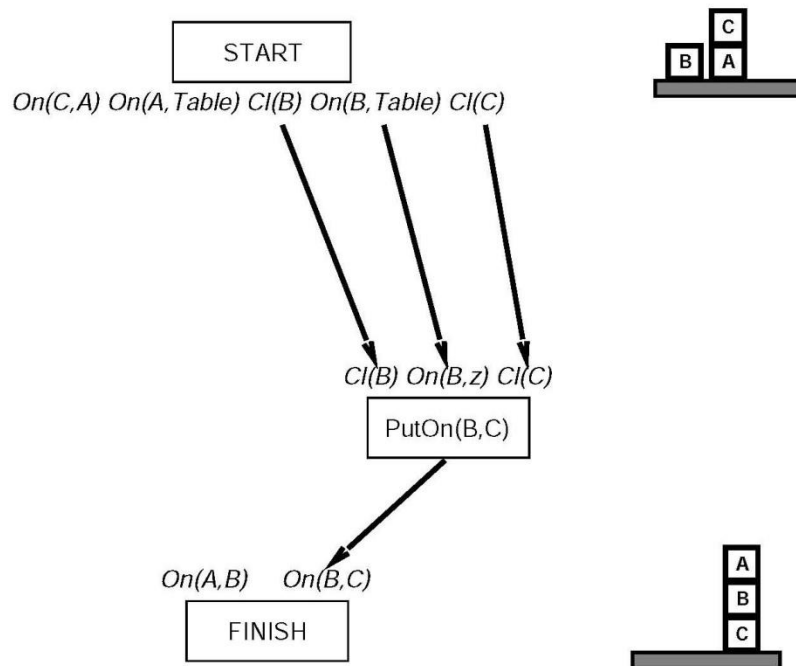
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Chapter 11 13



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Example contd.



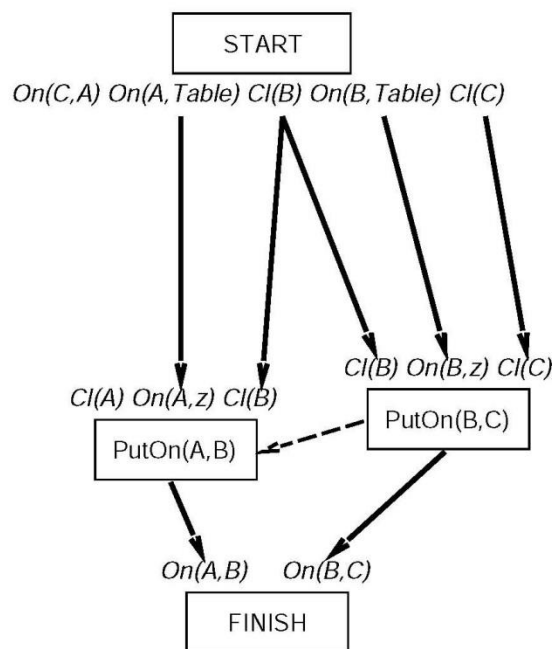
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Chapter 11 14

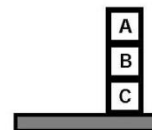


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Example contd.



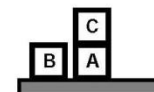
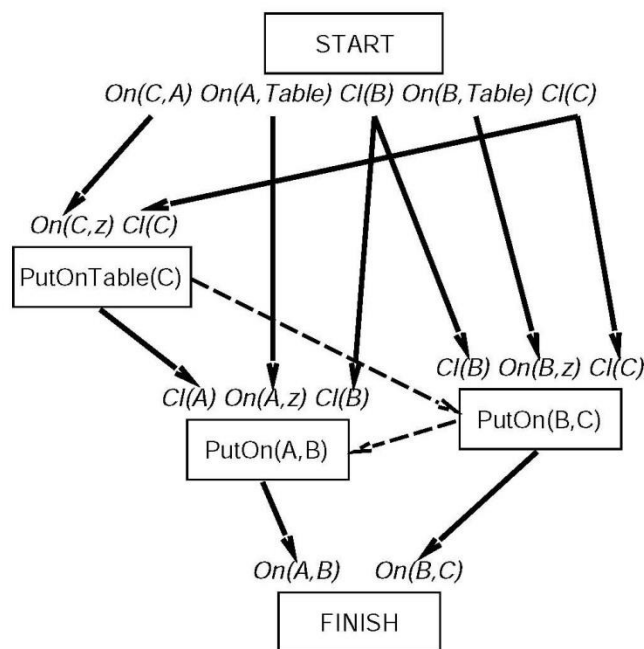
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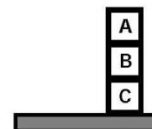
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Example contd.



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

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





Summary

Unpredictability of action outcomes in planning has the following implications:

- Plans with long sequences of interdependent actions are inappropriate
- Execution monitoring is useful
- Conditional plans are useful



作业

■ 10.4

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欢迎批评指正！
谢谢！

2019.11.05

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