Planning

Chapter 10
Overview

The blocks world

How to achieve the goal from the start?
Overview

- Problem-solving is searching and moving through a state space.
Overview

• Problem-solving is searching and moving through a state space.

• Planning is searching for successful paths through a state space.
Overview

- **Planning** is the process of computing several steps of a *problem-solving* procedure before executing them.

- Planning = problem sloving *in advance.*
Overview

• Planning is important if solutions cannot be undone.

• If the universe is not predictable, then a plan can fail ⇒ dynamic plan revision.
The Blocks World

Planning = generating a sequence of actions to achieve the goal from the start
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Actions:

• UNSTACK(A, B)
• STACK(A, B)
• PICKUP(A)
• PUTDOWN(A)
The Blocks World

Conditions and results:

• ON(A, B)

• ONTABLE(A)

• CLEAR(A)

• HOLDING(A)

• ARMEMPTY
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Specification of actions:

• PRECONDITION: list of predicates that must be true for an operator to be applied.

• ADD: list of new predicates that an operator causes to become true.

• DELETE: list of old predicates that an operator causes to become false.

• Predicates not in ADD nor DELETE are unaffected.
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Specification of actions:

STACK(x, y):

\( P \): CLEAR(y) \( \land \) HOLDING(x)

\( D \): CLEAR(y) \( \land \) HOLDING(x)

\( A \): ARMEMPTY \( \land \) ON(x, y)

UNSTACK(x, y):

\( P \): ON(x, y) \( \land \) CLEAR(x) \( \land \) ARMEMPTY

\( D \): ON(x, y) \( \land \) ARMEMPTY

\( A \): HOLDING(x) \( \land \) CLEAR(y)
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Specification of actions:

PICKUP(x):

\[ \begin{align*}
 P & : \text{CLEAR}(x) \land \text{ONTABLE}(x) \land \text{ARMEMPTY} \\
 D & : \text{ONTABLE}(x) \land \text{ARMEMPTY} \\
 A & : \text{HOLDING}(x)
\end{align*} \]

PUTDOWN(x):

\[ \begin{align*}
 P & : \text{HOLDING}(x) \\
 D & : \text{HOLDING}(x) \\
 A & : \text{ONTABLE}(x) \land \text{ARMEMPTY}
\end{align*} \]
The Blocks World

start: \( \text{ON}(B, A) \land \text{ONTABLE}(A) \land \text{ONTABLE}(C) \land \text{ONTABLE}(D) \land \text{ARMEMPTY} \)

goal: \( \text{ON}(C, A) \land \text{ON}(B, D) \land \text{ONTABLE}(A) \land \text{ONTABLE}(D) \land \)
Goal Stack Planning

Stack
- Goals
- Operators to satisfy the Goals

+ Database
- Current situation
- Specification of Operators/Actions
Goal Stack Planning

Push the original goal to the stack. Repeat until the stack is empty:

- If stack top is a compound goal, push its unsatisfied subgoals to the stack.
- If stack top is a single unsatisfied goal, replace it by an operator that makes it satisfied and push the operator’s precondition to the stack.
- If stack top is an operator, pop it from the stack, execute it and change the database by the operation’s affects.
- If stack top is a satisfied goal, pop it from the stack.
Goal Stack Planning

start:  ON(B, A) ∧
       ONTABLE(A) ∧
       ONTABLE(C) ∧
       ONTABLE(D) ∧
       ARMEMPTY

goal:  ON(C, A) ∧
       ON(B, D) ∧
       ONTABLE(A) ∧
       ONTABLE(D) ∧
Goal Stack Planning

Stack

ON(C, A)
ON(B, D)
ON(C, A) ∧ ON(B, D) ∧ OTAD

Database

ON(B, A)
OTACD
ARMEMPTY

CLEAR(A)
HOLDING(C)
CLEAR(A) ∧ HOLDING(C)
STACK(C, A)
ON(B, D) ∧
ON(C, A) ∧ ON(B, D) ∧ OTAD

ON(B, A)
OTACD
ARMEMPTY
Goal Stack Planning

Plan

1. UNSTACK(B, A)
2. STACK(B, D)
3. PICKUP(C)
4. STACK(C, A)
Goal Stack Planning

start: \( \text{ON}(C, A) \land \text{ONTABLE}(A) \land \text{ONTABLE}(B) \land \text{ARMEMPTY} \)

goal: \( \text{ON}(A, B) \land \text{ON}(B, C) \)

Sussman Anomaly (1975)
Goal Stack Planning

Plan

1. UNSTACK(C, A)
2. PUTDOWN(C)
3. PICKUP(A)
4. STACK(A, B)
5. UNSTACK(A, B)
6. PUTDOWN(A)
7. PICKUP(B)
8. STACK(B, C)
9. PICKUP(A)
10. STACK(A, B)
Goal Stack Planning

Plan

1. UNSTACK(C, A)
2. PUTDOWN(C)
3. PICKUP(A)
4. STACK(A, B)
5. UNSTACK(A, B)
6. PUTDOWN(A)
7. PICKUP(B)
8. STACK(B, C)
9. PICKUP(A)
10. STACK(A, B)
Questions

• Why stacks used?

• Why a compound goal retained in the stack with its subgoals?

• Does the order of subgoals in the stack matter?
Linear vs. Non-Linear Planning

• Goal Stack planning is **linear**: satisfies subgoals sequentially, one after another.

• **Non-linear planning**: consider interaction among subgoals.
Homework

Exercises:
1-4, Chapter 13, Rich&Knight AI Textbook
Chapter 7 of the Vietnamese Textbook