Goal stack planning

Illustration: Blocks world

To illustrate the goal stack planning approach, we consider the blocks world domain.

1. The objects of the blocks world

Start: ON(C,A) Goal: ON(B,C) and ON(A,B)

- A flat surface on which blocks can be placed.

- A number of square blocks, all of the same size.

- A robot arm that can manipulate the blocks.

- Blocks can be stacked one upon another.

2. Predicates and relations to describe the state of the blocks world

- **Predicate Meaning**

- ON(x, y) Block x is on block y

- ONTABLE(x) Block x is on table.

- CLEAR(x) There is nothing on top of block x

- HOLDING(x) The arm is holding block x

- ARMEMPTY The arm is holding nothing.
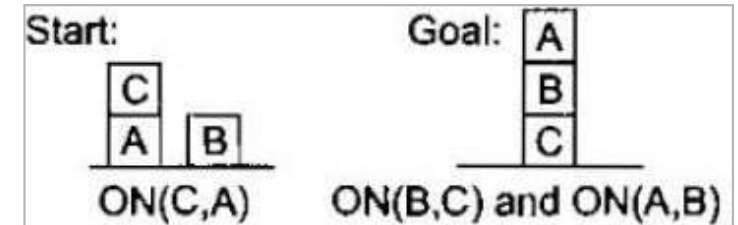
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3. Actions

The following are the available actions in the blocks world.

Action	Meaning
UNSTACK(x,y)	Pick up block x from its current position on block *y* and hold it in the arm
STACK(x,y)	Place block x held in the arm on block y.
PICKUP(x)	Pick up block x from table and hold it.
PUTDOWN(x)	Put block x held in the arm down on the table.

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The PRECONDITION list (the list of predicates that should be true to apply the action), ADD list (the list of predicates that become true after the action) and DELETE list (the list of predicates that become false after the action) associated with the various actions are given below..

Action	PRECONDITION list	ADD list	DELETE list
UNSTACK(x,y)	ARMEMPTY, CLEAR(x), ON(x. y)	HOLDING(x), CLEAR(y)	ARMEMPTY
STACK(x, y)	HOLDING(x), CLEAR(y)	ARMEMPTY, ON(x,y), CLEAR(x)	
PICKUP(x)	ARMEMPTY, CLEAR(x).	HOLDING(x)	ARMEMPTY
PUTDOWN(x)	HOLDING(x).	ARMEMPTY, ONTABLE(x), CLEAR(x)	

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4. Problem

Given the initial and the final states of a blocks world with four blocks as shown in Figure use goal stack planning algorithm to obtain a plan for achieving the goal state.

Fig: A simple blocks world problem: Initial state on the left and the goal state on the right

5. Solution

Step 1. The initial state can be described by the statement:

ON(B,A)^ONTABLE(A)^ONTABLE(C)^ONTABLE(D)^ARMEMPTY

The goal state can be specified by the statement:

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 2. We create a stack and call it GS. We initialize GS to be empty.
(empty)

Step 3. We push the goal state to the stack:

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

Step 4. The goal state can be divided into four components, namely,

ON(C,A) , ON(B,D) , ONTABLE(A) , and ONTABLE(D)

Of these the last two are true in the initial state. We push the first two components to the stack GS.

ON(C,A)

ON(B,D)

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 5. Consider the top item in GS which is ON(C,A). Check whether it is true in current state. It is not. Find an action which makes it true. the action is STACK(C,A).We replace ON(C,A) by STACK(C,A) to get the following GS.

STACK(C,A)

ON(B,D)

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

Step 6. To apply the action STACK(C,A) the preconditions CLEAR(A)^HOLDING(C) must be true. This precondition and also its components are also pushed to the stack GS.

CLEAR(A)
HOLDING(C)
CLEAR(A) ^ HOLDING(C)
STACK(C,A)
ON(B,D)
ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 7. We now check whether CLEAR(A) is true. It is not. The only operator that make it true is UNSTACK(B,A). So we replace CLEAR(A) by UNSTACK(B,A).

UNSTACK(B,A)

HOLDING(C)

CLEAR(A) ^ HOLDING(C)

STACK(C,A)

ON(B,D)

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

Step 8. To apply UNSTACK(B,A), the precondition ON(B,A)^CLEAR(B)^ARMEMPTY must be true. We add this precondition and its components to the stack GS.

ON(B,A)
CLEAR(B)
ARMEMPTY
ON(B,A) ^ CLEAR(B) ^ ARMEMPTY
UNSTACK(B,A)
HOLDING(C)
CLEAR(A) ^ HOLDING(C)
STACK(C,A)
ON(B,D)
ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 9. The top element ON(B,A) is true and so we pop it off from the stack. The next element CLEAR(B) is also true and so we pop it off also. At the current state, the arm is not holding anything and so ARMEMPTY is also true and we pop it off also. Sine each of the components of the next statement is true, the compounded statement is also true. Thus it is also popped off from the stack GS. At this stage the stack is as follows.

UNSTACK(B,A)
HOLDING(C)
CLEAR(A) ^ HOLDING(C)
STACK(C,A)
ON(B,D)
ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 10. The top element of the stack is UNSTACK(B,A). The preconditions for applying this action are satisfied.

(a) We now apply this operator to get a new world state.

(b) We record that UNSTACK(B,A) is the first operator of the solution sequence.

(c) The state of the world is specified by the following statements:

ONTABLE(A),ONTABLE(C),ONTABLE(D);
HOLDING(B),CLEAR(A)

(d) The goal stack GS is now

HOLDING(C)
CLEAR(A) ^ HOLDING(C)
STACK(C,A)
ON(B,D)
ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D).

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Step 11. The top element is HOLDING(C) , which is false. Find the action and its precondition list. Push into the GS.

The goal stack GS is now

ARMEMPTY

CLEAR(C)

ARMEMPTY ^ CLEAR(C)

PICKUP(C)

CLEAR(A) ^ HOLDING(C)

STACK(C,A)

ON(B,D)

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 12. The top element is ARMEMPTY , which is false. Find the action and its precondition list. Push into the GS.

The goal stack GS is now

HOLDING(B)
PUTDOWN(B)
CLEAR(C)
ARMEMPTY ^ CLEAR(C)
PICKUP(C)
CLEAR(A) ^ HOLDING(C)
STACK(C,A)
ON(B,D)
ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 13. The top element is HOLDING(B) , which is True. Pop it. Preconditions of action PUTDOWN(B) is true. Perform it and add to plan sequence.

ONTABLE(A),ONTABLE(C),ONTABLE(D); ONTABLE(B),CLEAR(A), CLEAR(C), CLEAR(D),CLEAR(B)

The goal stack GS is now

CLEAR(C)
ARMEMPTY ^ CLEAR(C)
PICKUP(C)
CLEAR(A) ^ HOLDING(C)
STACK(C,A)
ON(B,D)
ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 14. The top element is CLEAR(C) , which is True. Pop it. Next top element is ARMEMPTY ^ CLEAR(C), which is also True. Pop it.

Precondition of action PICKUP(C) is true. Perform it and add to plan sequence.

ONTABLE(A),ONTABLE(B),ONTABLE(D);
HOLDING(C),CLEAR(A), CLEAR(B), CLEAR(D)

The goal stack GS is now

CLEAR(A) ^ HOLDING(C)
STACK(C,A)
ON(B,D)
ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 15. The top element is CLEAR(A) ^ HOLDING(C) , which is True. Pop it.

Precondition of action STACK(C,A) is true. Perform it and add to plan sequence.

ONTABLE(A),ONTABLE(B),ONTABLE(D);

ARMEMPTY,ON(C,A), CLEAR(B), CLEAR(D)

The goal stack GS is now

ON(B,D)

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 16. The top element is ON (B,D), which is False. Find action and precondition list.

STACK(B,D) , HOLDING(B) AND CLEAR(D)

The goal stack GS is now

HOLDING(B)

 CLEAR(D)

HOLDING(B) ^ CLEAR(D)

STACK(B,D)

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

Goal stack planning

Step 17. The top element is HOLDING(B), which is False. Find action and precondition list.

PICKUP(B) - action, ARMEMPTY, CLEAR(B) Precondition

The goal stack GS is now

ARMEMPTY

CLEAR(B)

ARMEMPTY ^ CLEAR(B)

 PICKUP(B)

 CLEAR(D)

HOLDING(B) ^ CLEAR(D)

STACK(B,D)

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

Step 18. The top element is ARMEMPTY, which is true. CLEAR(B) , ARMEMPTY ^ CLEAR(B) are true . POP it. Find action and precondition list.

PICKUP(B) - which is action , precondition true . Add to plan list

The goal stack GS is now

CLEAR(D)

HOLDING(B) ^ CLEAR(D)

STACK(B,D)

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

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Step 19. The top elements are CLEAR(D) , HOLDING(B) ^ CLEAR(D) ere true. Pop it.

STACK(B,D) - which is action , preconditions are true . Add to plan list

The goal stack GS is now

ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D)

Step 18. ON(C,A) ^ ON(B,D) ^ ONTABLE(A) ^ ONTABLE(D) is true. Pop it.

The goal stack GS is now

Empty