COMPSCI 270: Artificial Intelligence

Homework 4: Planning

Due April 2 before the beginning of class

Please read the rules for assignments on the course web page. Of course, **do not share code**. Acknowledge any help you received and any sources you used. If you are not sure whether you are allowed to use something, ask. Please use Piazza for questions and Gradescope to turn in the assignment.

1 Introduction

In this brief homework assignment, we will consider another block stacking domain. Unlike the ones considered before, in this domain, a block needs to be stacked on *two* other blocks, and those two blocks must be touching each other. (Or, the block can be put on the table.) Thus, we no longer just consider whether a block is clear; we must consider whether the left side of its top is clear `(left-clear ?block)`, and whether the right side of its top is clear `(left-clear ?block)`. Furthermore we need to keep track of whether two blocks are adjacent `(touching ?left-block ?right-block)`, as well as whether there is currently nothing to the left or right of a block `(nothing-to-left ?block)`, `(nothing-to-right ?block)`.

Because a block may be touching another block, we can no longer use the same kind of gripper that we used before. Instead, we use one that can grab a block *from the top right*. This means that for us to be able to pick up a block, it needs to have nothing on top of it, *and* there needs to be nothing adjacent to the right of it.

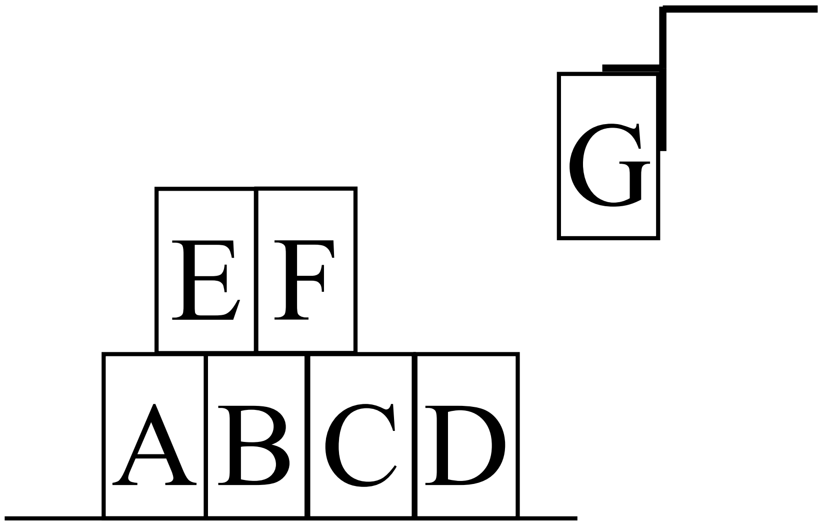


Figure 1: Example Configuration

Consider the example in Figure 1. The arm is currently holding block G. It could place it on top of E and F; it could place it on top of C and D, so that F will be touching it; it could place it on the table so D will be touching it; or it could place it on the table in a new stack so that nothing will be touching it. It *cannot* put G next to A, because it has to come in from the top right.

If the arm weren't currently holding G, it could pick up either F or D. It *cannot* pick up E, because it has to come in from the top right. We have to consider a number of different cases, all corresponding to different actions. For picking up a block, it matters whether it is touching a block to the left (in which case we need to update that for the block to the left) or not; it also matters whether it is on top of other blocks (in which case we need to update that for the blocks below) or not. In the former case we add `-touching` to the action and in the latter case `-stacked`. E.g., action `pick-up-from-top-right-touching-stacked` is picking up a block that is on top of other blocks *and* touching another block on the left. The same is true for when we put blocks down.

2 Submission Instructions and Testing

In the domain file (`block-domain.pddl`) you're given, the predicates and some of the actions have already been defined and you need to implement the remaining action schemas:

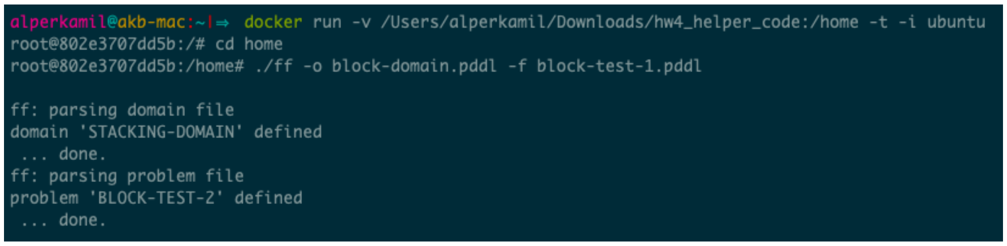
- `take-from-bag`
- `pick-up-from-top-right-stacked`
- `pick-up-from-top-right-touching`
- `pick-up-from-top-right`
- `put-down-from-top-right-stacked`
- `put-down-from-top-right-touching`
- `put-down-from-top-right`

You should **not** define new predicates and actions. You should submit `block-domain.pddl` to the Gradescope assignment "Homework 4: Planning", and you should upload it directly without zipping.

You can use the fast-forward solver (`ff`), the executable file included in the helper code, to test your implementation. You need to run `ff` on a Linux OS, or alternatively you can run an Ubuntu image using Docker containers on Mac or Windows. Once you download and install Docker, you can run it from the command line:

```
$ docker run -v [/path/to/hw/directory]:/home -t -i ubuntu
$ cd home
$ ./ff -o block-domain.pddl -f block-test-1.pddl
```

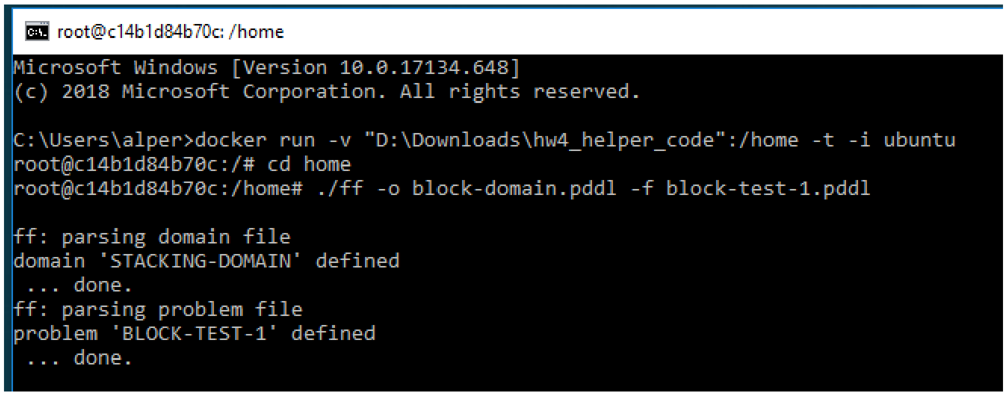
You also need to give Docker the permission to access the directory.



```
alperkamil@akb-mac:~|⇒  docker run -v /Users/alperkamil/Downloads/hw4_helper_code:/home -t -i ubuntu
root@802e3707dd5b:/# cd home
root@802e3707dd5b:/home# ./ff -o block-domain.pddl -f block-test-1.pddl

ff: parsing domain file
domain 'STACKING-DOMAIN' defined
 ... done.
ff: parsing problem file
problem 'BLOCK-TEST-2' defined
 ... done.
```

Figure 2: Example Execution on Mac



```
root@c14b1d84b70c: /home
Microsoft Windows [Version 10.0.17134.648]
(c) 2018 Microsoft Corporation. All rights reserved.

C:\Users\alper>docker run -v "D:\Downloads\hw4_helper_code":/home -t -i ubuntu
root@c14b1d84b70c:/# cd home
root@c14b1d84b70c:/home# ./ff -o block-domain.pddl -f block-test-1.pddl

ff: parsing domain file
domain 'STACKING-DOMAIN' defined
 ... done.
ff: parsing problem file
problem 'BLOCK-TEST-1' defined
 ... done.
```

Figure 3: Example Execution on Windows

We have given you three instance files to test your code with; we have kept others secret for testing purposes. Please note that the planner is *not* guaranteed to give an *optimal* plan, and as you can see it comes up with some pretty strange plans. That is OK.

- `block-test-1.pddl`
  - Reverse the order of blocks in a row.

    ```
    Initial State:
     B1--B2--B3--B4
    Goal:
     B4--B3--B2--B1
    ```
  - Plan:

    ```
    step    0: PICK-UP-FROM-TOP-RIGHT-TOUCHING B4 B3
            1: PUT-DOWN-FROM-TOP-RIGHT B4
            2: PICK-UP-FROM-TOP-RIGHT-TOUCHING B3 B2
            3: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B3 B4
            4: PICK-UP-FROM-TOP-RIGHT-TOUCHING B2 B1
            5: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B2 B3
            6: PICK-UP-FROM-TOP-RIGHT B1
            7: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B1 B2
    ```

- `block-test-2.pddl`
  - Construct a pyramid using the blocks in the bag.

    ```
    Goal:
         B3
       XX--B2
     XX--XX--B1
    ```
  - Plan:

    ```
    step    0: TAKE-FROM-BAG B1
            1: PUT-DOWN-FROM-TOP-RIGHT B1
            2: TAKE-FROM-BAG B2
            3: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B2 B1
            4: TAKE-FROM-BAG B3
            5: PUT-DOWN-FROM-TOP-RIGHT B3
            6: PICK-UP-FROM-TOP-RIGHT-TOUCHING B2 B1
            7: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B2 B3
            8: PICK-UP-FROM-TOP-RIGHT B1
            9: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B1 B2
           10: TAKE-FROM-BAG B6
           11: PUT-DOWN-FROM-TOP-RIGHT B6
           12: PICK-UP-FROM-TOP-RIGHT-TOUCHING B1 B2
           13: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B1 B6
           14: PICK-UP-FROM-TOP-RIGHT-TOUCHING B2 B3
           15: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B2 B1
           16: PICK-UP-FROM-TOP-RIGHT B3
           17: PUT-DOWN-FROM-TOP-RIGHT-STACKED B3 B1 B2
           18: TAKE-FROM-BAG B5
           19: PUT-DOWN-FROM-TOP-RIGHT B5
           20: TAKE-FROM-BAG B4
           21: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B4 B5
           22: PICK-UP-FROM-TOP-RIGHT-STACKED B3 B1 B2
           23: PUT-DOWN-FROM-TOP-RIGHT B3
           24: PICK-UP-FROM-TOP-RIGHT-TOUCHING B2 B1
           25: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B2 B3
           26: PICK-UP-FROM-TOP-RIGHT-TOUCHING B1 B6
           27: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B1 B4
           28: PICK-UP-FROM-TOP-RIGHT-TOUCHING B2 B3
           29: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B2 B1
           30: PICK-UP-FROM-TOP-RIGHT B3
           31: PUT-DOWN-FROM-TOP-RIGHT-STACKED B3 B1 B2
           32: PICK-UP-FROM-TOP-RIGHT B6
           33: PUT-DOWN-FROM-TOP-RIGHT-STACKED B6 B5 B4
           34: PICK-UP-FROM-TOP-RIGHT-STACKED B3 B1 B2
           35: PUT-DOWN-FROM-TOP-RIGHT B3
           36: PICK-UP-FROM-TOP-RIGHT-TOUCHING B2 B1
           37: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING-STACKED B2 B6 B4 B1
           38: PICK-UP-FROM-TOP-RIGHT B3
           39: PUT-DOWN-FROM-TOP-RIGHT-STACKED B3 B6 B2
    ```

- `block-test-3.pddl`
  - Destruct a pyramid.

```
Initial State:
     B6
   B4--B5
 B1--B2--B3
Goal:
 B6--B5--B4--B3--B2--B1
```

  - Plan:

```
step    0: PICK-UP-FROM-TOP-RIGHT-STACKED B6 B4 B5
        1: PUT-DOWN-FROM-TOP-RIGHT B6
        2: PICK-UP-FROM-TOP-RIGHT-TOUCHING-STACKED B5 B4 B2 B3
        3: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B5 B6
        4: PICK-UP-FROM-TOP-RIGHT-STACKED B4 B1 B2
        5: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B4 B5
        6: PICK-UP-FROM-TOP-RIGHT-TOUCHING B3 B2
        7: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B3 B4
        8: PICK-UP-FROM-TOP-RIGHT-TOUCHING B2 B1
        9: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B2 B3
       10: PICK-UP-FROM-TOP-RIGHT B1
       11: PUT-DOWN-FROM-TOP-RIGHT-TOUCHING B1 B2
```