CS 560: Homework 9

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In [50]:

```
from hw4standard import *

ProveDebug = 0

def proveall(query,kb,indent=""):
    vars = findvariables(query,[])
    if ProveDebug > 0:
        print("%sVars in query are %s" % (indent,vars))
    answer = [['yes']+vars]+query
    if ProveDebug > 0:
        print("%sInitial answer clause is %s" % (indent,prettyclause(answer)))

    # the initial frontier is a list whose only element is the initial
    # answer clause
    frontier = [answer]
    answers = []

    while frontier:
        # give answer clause fresh variables
        answer = frontier[0]
        frontier = frontier[1:]
        if len(answer) == 1:
            yesatom = answer[0]
            answer = []
            if ProveDebug > 0:
                str = "%sFound answer:" % indent
                for var,val in zip(vars,yesatom[1:]):
                    str += " %s=%s" % (var,prettyexpr(val))
                print(str + "\n")
            for var,val in zip(vars,yesatom[1:]):
                answer += [var,val]
            answers.append(answer)
            continue

        # give it fresh variables
        if ProveDebug:
            print("%sTrying to prove     : %s" % (indent,prettyclause(answer)))
        answer = freshvariables(answer)
        if ProveDebug:
            print("%s  after fresh vars  : %s" % (indent,prettyclause(answer)))

        neighbors = []
        firstatom = answer[1]
        firstpred = firstatom[0]

        if firstpred == 'not':
            result = proveall(firstatom[1:],kb,"| "+indent)
            if result == []:
                neighbor = answer[0:1]+answer[2:]
                if ProveDebug:
                    print("%s  Neighbor  : %s" % (indent,neighbor))
                neighbors.append(neighbor)
        elif firstpred == "=":
            subs = {}
            result = unify(firstatom[1],firstatom[2],subs)
            if result != False:
                neighbor = substitute(answer[0:1]+answer[2:],subs)
                if ProveDebug:
                    print("%s  Neighbor  : %s" % (indent,neighbor))
                neighbors.append(neighbor)
        else:
            for rule in kb:
                subs = {}
                if not unify(rule[0],answer[1],subs):
                    continue

                if ProveDebug:
                    print("%s    using rule %s" % (indent,prettyclause(rule)))
                    str = ""
                    for s in subs:
                        str += " %s/%s" % (s,prettyexpr(subs[s]))
                    print("%s    proven by %s with %s" %
                          (indent,prettyexpr(rule[0]),str))
                # create answer clause
                answercopy = answer[0:1]+rule[1:]+answer[2:]
                # apply substitution
                answercopy = substitute(answercopy,subs)
                if ProveDebug:
                    print("%s    result: %s" % (indent,prettyclause(answercopy)))
                neighbors.append(answercopy)

        if ProveDebug:
            print("%s  Found %d neighbors." % (indent,len(neighbors)))
        frontier = neighbors+frontier
    if ProveDebug:
        print("\n%sFound %d answers: %s" % (indent,len(answers),answers))
    return answers

```

In [51]:
```
kb = [[['poss',['pickup','A','B'],'S'],
       ['block','B'],['block','A'],
       ['empty','S'],['clear','A','S'],
       ['on','A','B','S']],
      [['poss',['pickup','A','B'],'S'],
       ['table','B'],['block','A'],['empty','S'],['clear','A','S'],['on','A','B','S']],
      [['poss',['putdown','A','B'],'S'],
       ['block','B'],['holding','A','S'],['clear','B','S']],
      [['poss',['putdown','A','B'],'S'],
       ['table','B'],['holding','A','S']],
      [['on','A','B',['do',['putdown','A','B'],'S']]],
      [['on','A','B',['do','Action','S']],
       ['on','A','B','S'],['not',['=','Action',['pickup','A','X']]]],
      [['clear','B',['do',['putdown','B','X'],'S']]],
      [['clear','B',['do',['pickup','X','B'],'S']],
       ['not',['table','B']]],
      [['clear','B',['do','A','S']],
       ['clear','B','S'],['not',['=','A',['putdown','X','B']]],['not',['=','A',['pickup','B','Y']]]],
      [['empty',['do',['putdown','A','B'],'S']]],
      [['empty',['do','A','S']],
       ['empty','S'],['not',['=','A',['pickup','X','Y']]]],
      [['empty',['do','A','S']],
       ['empty','S'],['not',['=','A',['pickup','X','Y']]]],
      [['holding','B',['do',['pickup','B','X'],'S']]],
      [['holding','B',['do','A','S']],
       ['holding','B','S'],['not',['=','A',['putdown','B','X']]]],
      [['block','a']],
      [['block','b']],
      [['block','c']],
      [['table','t']],
      [['on','a','b','init']],
      [['on','b','t','init']],
      [['on','c','t','init']],
      [['empty','init']],
      [['clear','a','init']],
      [['clear','c','init']],
      [['goal','S'],['on','a','t','S'],['on','b','c','S']]]
```

Question 1

Before you attempt to write the forward planner, make sure you understand how to use the **proveall** procedure. Give the python code to call proveall to prove the following.

a is on b in the initial world.

The action of picking up a off of b is possible in the initial world.

The robot is holding a after it picks up a off of b from the initial world.

The robot's hand is empty after putting a on the table, after picking up a off of b from the initial world.

In [52]:
```
query1 = [['on','a','b','init'],
          ['poss',['pickup','a','b'],'init'],
          ['holding','a',['do',['pickup','a','b'],'init']],
          ['empty',['do',['putdown','a','t'],['do',['pickup','a','b'],'init']]]]

proveall(query=query1,kb=kb,indent="")
```

Out[52]:
```
[[]]
```

Question 2

In [53]:
```
query2 = [['on','Block_on_table_in_inital_world','t','init'],
          ['poss','Action_possible_in_initail_world','init'],
          ['poss','Action_possible_after_pickup_a',['do',['pickup','a','b'],'init']]]

ans = proveall(query=query2, kb=kb, indent="")
ans
```

Out[53]:
```
[['Block_on_table_in_inital_world',
  'b',
  'Action_possible_in_initail_world',
  ['pickup', 'a', 'b'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 'b']],
 ['Block_on_table_in_inital_world',
  'b',
  'Action_possible_in_initail_world',
  ['pickup', 'a', 'b'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 'c']],
 ['Block_on_table_in_inital_world',
  'b',
  'Action_possible_in_initail_world',
  ['pickup', 'a', 'b'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 't']],
 ['Block_on_table_in_inital_world',
  'b',
  'Action_possible_in_initail_world',
  ['pickup', 'c', 't'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 'b']],
 ['Block_on_table_in_inital_world',
  'b',
  'Action_possible_in_initail_world',
  ['pickup', 'c', 't'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 'c']],
 ['Block_on_table_in_inital_world',
  'b',
  'Action_possible_in_initail_world',
  ['pickup', 'c', 't'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 't']],
 ['Block_on_table_in_inital_world',
  'c',
  'Action_possible_in_initail_world',
  ['pickup', 'a', 'b'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 'b']],
 ['Block_on_table_in_inital_world',
  'c',
  'Action_possible_in_initail_world',
  ['pickup', 'a', 'b'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 'c']],
 ['Block_on_table_in_inital_world',
  'c',
  'Action_possible_in_initail_world',
  ['pickup', 'a', 'b'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 't']],
 ['Block_on_table_in_inital_world',
  'c',
  'Action_possible_in_initail_world',
  ['pickup', 'c', 't'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 'b']],
 ['Block_on_table_in_inital_world',
  'c',
  'Action_possible_in_initail_world',
  ['pickup', 'c', 't'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 'c']],
 ['Block_on_table_in_inital_world',
  'c',
  'Action_possible_in_initail_world',
  ['pickup', 'c', 't'],
  'Action_possible_after_pickup_a',
  ['putdown', 'a', 't']]]
```

Question 3

In [58]:

```
def forward_planner(kb):

    '''The frontier will begin with
    just the single element init.'''
    new_frontier = ['init']

    '''On each iteration (hint: while loop),
    you first see if you can prove that goal
    is true of the current world.'''
    while len(new_frontier) > 0:

        #current world
        current_world = new_frontier[0]

        print("World:", current_world)

        '''If it is, then you can stop.'''
        ans = proveall([['goal',current_world]], kb)
        if len(ans) > 0: return True

        '''Otherwise, you need to find all actions that are
        possible (using proveall) in the current world. '''
        print("Goal is not true")
        possible_actions = proveall([['poss','Action',current_world]], kb)

        '''For each possible action, you can construct the new world as
        do(Action,World). This will give you all of the neighbors of the
        current world. You then add the neighbors to the frontier using a
        breath-first search strategy.'''
        print("Neighbor worlds:")
        for action in possible_actions:
            new_frontier.append(['do',action[1],current_world])
            print("    ", ['do',action[1],current_world])
        new_frontier = new_frontier[1:]
        print("\n")

    # empty front
    print("No solution found")
    return False

forward_planner(kb)
```

```
World: init
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'b'], 'init']
    ['do', ['pickup', 'c', 't'], 'init']


World: ['do', ['pickup', 'a', 'b'], 'init']
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]
    ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]
    ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]


World: ['do', ['pickup', 'c', 't'], 'init']
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], 'init']]
    ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]


World: ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]


World: ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]


World: ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]


World: ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], 'init']]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'c', 'a'], ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], 'init']]]


World: ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]


World: ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]


World: ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
```

```
World: ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]


World: ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'b', 'a'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'b', 't'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]


World: ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]


World: ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'b', 'a'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'b', 'c'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'b', 't'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]


World: ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'c', 'b'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
    ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]


World: ['do', ['pickup', 'c', 'a'], ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 'a'], ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], 'init']]]]
    ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 'a'], ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], 'init']]]]


World: ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]]
    ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]]
    ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]]


World: ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]
Goal is not true
Neighbor worlds:
    ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]]
    ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], 'init']]]]


World: ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true

Neighbor worlds:
    ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'c', 'a'], ['do', ['putdown', 'c', 'a'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'c', 't'], ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
```

```
World: ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'b', 'a'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'b', 'a'], ['do', ['putdown', 'b', 'a'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'b', 't'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'b', 't'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'b', 't'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'b'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 'b'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 'c'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 'c'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'b', 'a'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
Goal is not true
Neighbor worlds:
    ['do', ['pickup', 'b', 'a'], ['do', ['putdown', 'b', 'a'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]
    ['do', ['pickup', 'c', 't'], ['do', ['putdown', 'b', 'a'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'ini
t']]]]]


World: ['do', ['putdown', 'b', 'c'], ['do', ['pickup', 'b', 't'], ['do', ['putdown', 'a', 't'], ['do', ['pickup', 'a', 'b'], 'init']]]]
```

Out[58]: True

Question 4

We are mimicing Prolog here and therefore implement a negation as failure strategy, eliminating the need to delay.

Question 5

In our implementation, the `proveall` function ensures that anything that we add to the frontier is possible in the state that it was resolved from. The frontire stores the entire history of resolutions.

Question 6

The strips planner we previously implemented checks for preconditions by simply ensuring that the preconditions predicate list for a given action is a subset of the world that that action is intended to be taken from. This does not allow for the use of derived predicates because simply ensuring that the preconditions predicate list is a subset of a world does not take into account the predicates that could be implied implied by that world.

Question 7

Execute a top-down theorem prover to be called with the current world as the KB and preconditions of a desired action that are not contained within that world as the query. With this set up, preconditions could be derived on the fly.

Question 8

Yes, in this case we can use derived predicates because the input to `proveall` takes the form of a `poss` function. The `proveall` function will attempt to resolve any preconditions using the knowledge base.

Question 9

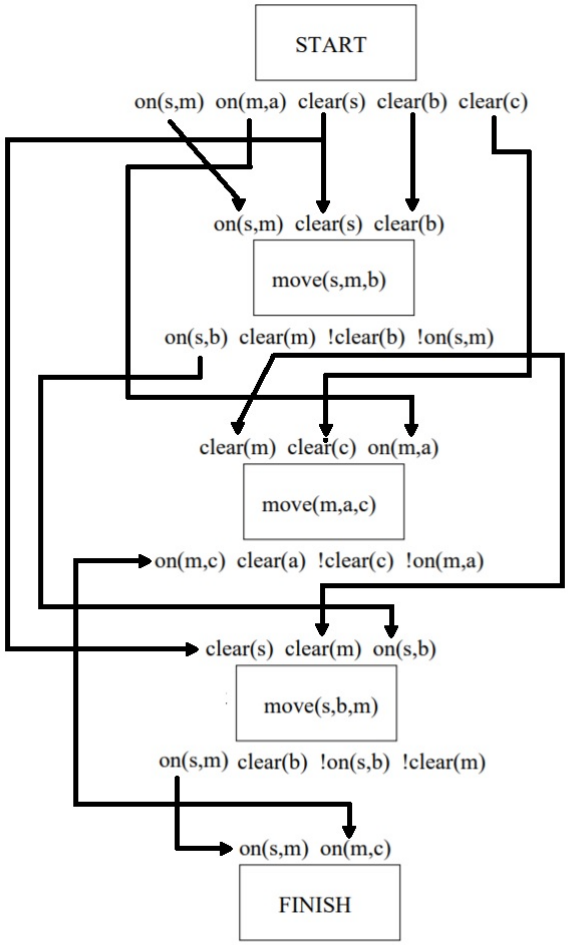
The primative `clear(A)` could be defined as a derivative in terms of the `on(B,A)` predicate like so:
$clear(A) \longleftarrow \neg on(B, A)$

`empty` could be defined using the negation of `holding(A)` like so:
$empty \longleftarrow \neg holding(A)$

Question 10

I can only spot a single threat in this planner. In the two moves that are in parallel with causal links to the finish state, the one on the left has an add list that includes `!clear(m)` where the one on the right has a precondition of `clear(m)` . This is a clobber that can be resolved by having the action on the left follow the one on the right. By colapsing these actions from parallel to series in this way we have removed the threat and have a single, linearized solution.

Question 11



Question 12

```
subset([],_).
subset([Sub_head|Sub_rest],Set) :-
        member(Sub_head,Set),
        subset(Sub_rest,Set).

% Told use of subtract was ok in Slack
remove(Sub,Set,Rest) :-
        subset(Sub,Set),
        subtract(Set, Sub, Rest).
```

Question 13

```
neighbor([Plan,World],[[NewPlan],NewWorld]) :-
        action(NextAction,Pre,Add,Del),
        subset(Pre,World),
        remove(Del,World,NewWorldMinus),
        append(NewWorldMinus,Add,NewWorld),
        append(Plan,NextAction,NewPlan).
```

Question 14

```
plan([[CurrentPlan,CurrentWorld]|_]) :-
        goal(Goal),
        subset(Goal,CurrentWorld),
        write("\n Goal: "),
        write(Goal),
        write("\n CurrentWorld: "),
        write(CurrentWorld),
        write("\n CurrentPlan: "),
        write(CurrentPlan),
        !. % this cut will prevent infinite combos

plan([First|Frontier]) :-
        findall(New,neighbor(First,New),Neighbors),
        append(Frontier,Neighbors, Temp),
        plan(Temp).


test() :-
        initial(Initial),
        plan([[[],Initial]]
```

Output:

```
Goal: [on(c,b),on(b,a),on(a,t)]
CurrentWorld: [block(a),block(b),block(c),table(t),on(a,t),on(b,a),on(c,b),clear(c),empty]
CurrentPlan: [[[[[[pickup(a,b)|putdown(a,t)]|pickup(b,c)]|putdown(b,a)]|pickup(c,t)]|putdown(c,b)]]
true.
```