Knowledge Representation & Reasoning
COMP7021(Spring 2021)

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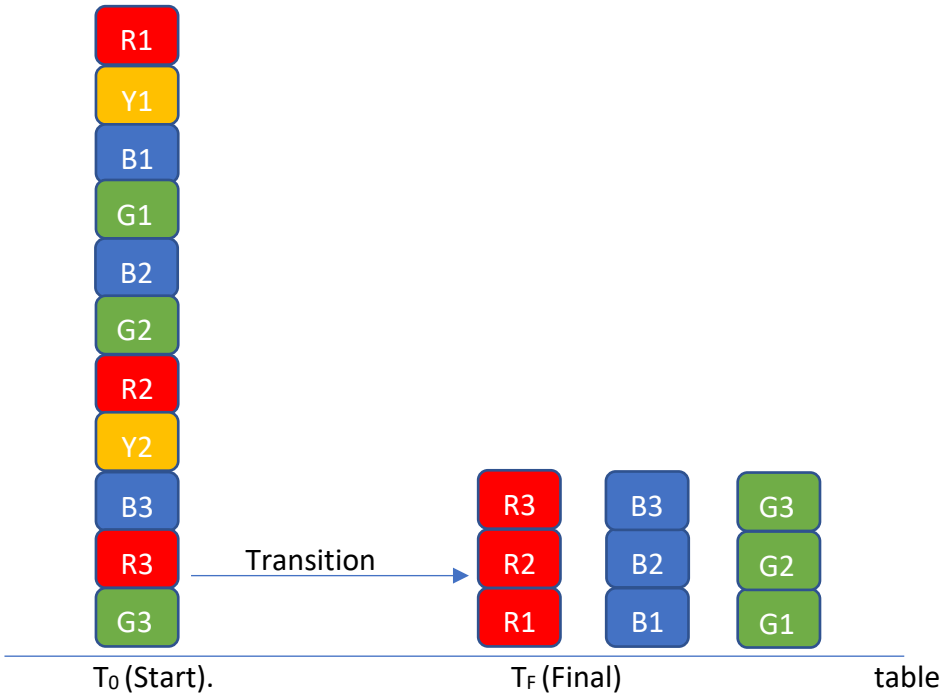
Report – Case Study (Coloured Cubes)

(a) Problem Domain Scenario:

Consider 11 cubes, out of which 3 cubes are red in color, 3 cubes are blue in color, 3 cubes are green in color and 2 cubes are yellow in color. They are stacked randomly on each other on a table and creating a single stack. We must perform 2 actions. One is "put" in which a robot must put a cube one at a time either on the table if there is an empty space and none of the cube placed matches the color of that cube, otherwise put the cube on the same color of the cube. Another action is "remove", in which a robot has to remove the cube which is yellow in color. Thus, in the final step we should have 3 stacks of cubes of colors red, blue, and green.

Below is the transition diagram which depicts above scenario:



Please note that we have denoted colours as names like r1 for first red cube, y1 for first Yellow cube etc.

(b) Complete System Description:

Formal Description - Signature:

cube = {r1,y1,b1,g1,b2,g2,r2,y2,b3,r3,g3}
loc = {r1,y1,b1,g1,b2,g2,r2,y2,b3,r3,g3,t}
inertial fluent on(C1,L1) which states Cube C1 is on location L1
defined fluent above(C1,L1) which states Cube C1 is above location L1
action = put(C1,L1) which states put Cube C1 at location L1, remove(C1) which states remove the cube C1.
n = 11
step = 0..n

System Description:

Causal Law:

put(C1, L1) causes on(C1, L1)

remove(C1) causes removed(C1)

State Constraints:

-on(C1,L1) if not on(C1,B1)

-on(C1,L1) if remove(C1)

-on(C1,L2) if on(C1,L1), L1 != L2

-on(C2,C) if on(C1,C), C1 != C2

above(C1,L1) if on(C1,L1)

above(C1,L1) if on(C1,C2), on(C2,L1)

Executability Conditions:

impossible put(C1,L1) if on(C2,C1), loc(L1)

impossible put(C1,C2) if on(C3,C1), on(C2,C4)

impossible put(C1,L1) if on(C1,L2), on(C2,L1), C1 != C2

(c) Clingo Program:

```
%% Signature
%% Statics

%% define cubes
cube(r1). cube(y1). cube(b1). cube(g1). cube(b2). cube(g2).
cube(r2). cube(y2). cube(b3). cube(r3). cube(g3).

%% define locations
loc(r1). loc(y1). loc(b1). loc(g1). loc(b2). loc(g2).
loc(r2). loc(y2). loc(b3). loc(r3). loc(g3). loc(t).


%% Intertial and defined fluents

fluent(inertial,on(C1,C2)) :- holds(on(C1,C2),I).
fluent(defined,above(C1,C2)) :- holds(above(C1,C2),I).


%% Setting step numbers

#const n=11.
step(0..n).


%%% cube not on location L at step 0, CWA
-holds(on(C1,L1), 0) :- not holds(on(C1,L1), 0), cube(C1),
loc(L1).

%% Encoding SD
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%% Causal Law

%% Putting cube B on location L at step I causes B to be on L at
step I+1
holds(on(C1,L1), I+1) :- occurs(put(C1,L1), I).

%% Removing C1 cube will cause removed C1 cube.
removed(C1) :- occurs(remove(C1), I), cube(C1).

%% State Constraints

%% if removal of a cube occur at step I, then it would not hold
any
%% relation at step I+1
-holds(on(C1,L1), I+1) :- occurs(remove(C1), I), cube(C1),
loc(L1).

%% A cube cannot be in two location at once
-holds(on(C1,L2), I) :- holds(on(C1,L1), I), L1 != L2, loc(L2).

%% Only one cube can be directly on top of one another.
-holds(on(C2,C),I) :- holds(on(C1,C),I), C1 != C2, cube(C),
cube(C2).

%% above(C1,L1) if on(C1,L1)
holds(above(C1,L1),I) :- holds(on(C1,L1),I).

%% above(C1,L1) if on(C1,C2), on(C2,L1)
holds(above(C1,L1),I) :- holds(on(C1,C2),I), holds(on(C2,L1),I).

%% Executability conditions:

%% It is impossible to move an occupied cube:
-occurs(put(C,T),I) :- holds(on(C1,C),I), loc(T).
-occurs(put(C,C2),I) :- holds(on(C1,C),I),
                        holds(on(C2,C3),I),
                        C1 != C2, C != C3.
%% It is impossible to move a cube onto
%% an occupied cube:
-occurs(put(C1,C),I) :- holds(on(C1,L),I),
                        holds(on(C2,C),I),
                        C1 != C2, C != t.


%% CWA for defined fluent
-holds(F,I) :- fluent(defined,F), not holds(F,I), step(I).
```

```
%% CWA for removed
-removed(B) :- not removed(B), cube(B).

%% Inertia rules

%% Inertia rule 1: Anything that holds at step I, will also hold
at step I+1 as long as no evidence shows its opposite.
holds(F,I+1) :- fluent(inertial,F), holds(F,I), not -holds(F,I+1),
I<n.

%% Inertia rule 2: Anything that does not hold at step I, will
also not hold at step I+1, as long as no evidence shows its
opposite.
-holds(F,I+1) :- fluent(inertial,F), -holds(F,I), not holds(F,I+1),
I<n.

%% Initial Configuration
holds(on(g3,t), 0). holds(on(r3,g3), 0). holds(on(b3,r3), 0).
holds(on(y2,b3), 0). holds(on(r2,y2), 0). holds(on(g2,r2), 0).
holds(on(b2,g2), 0). holds(on(g1,b2), 0). holds(on(b1,g1), 0).
holds(on(y1,b1), 0). holds(on(r1,y1), 0).


%% Encoding action
occurs(put(r1,t),0).
occurs(remove(y1),1).
occurs(put(b1,t),2).
occurs(put(g1,t),3).

occurs(put(b2,b1),4).
occurs(put(g2,g1),5).
occurs(put(r2,r1),6).
occurs(remove(y2),7).

occurs(put(b3,b2),8).
occurs(put(r3,r2),9).
occurs(put(g3,g2),10).

#show holds/2.
#show -removed/1.
#show removed/1.
```

(d) Query Evaluations:

1. Show all the states for holds:

   The Output below depicts every information of cubes placed at each state.
   Output:

   The above output contains information like:
   holds(on(r3,r2),11), holds(on(g3,g2),11), holds(on(b3,b2),11), holds(on(r2,r1),11), holds(on(g2,g1),11), holds(on(b2,b1),11), holds(on(r1,t),11), holds(on(g1,t),11), holds(on(b1,t),11).

   This exactly, is the 11th and final stage of our desired outcome.

2. Show the ones which are removed:

   The output below shows all the yellow cubes which were removed.
   Output:

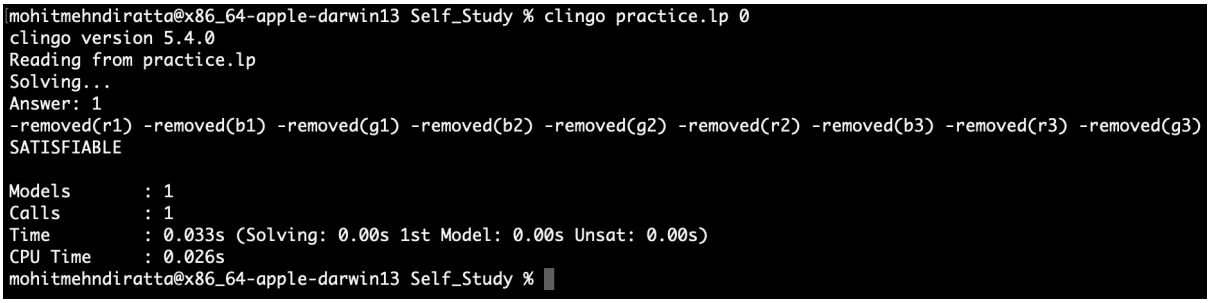
```
mohitmehndiratta@x86_64-apple-darwin13 Self_Study % clingo practice.lp 0
clingo version 5.4.0
Reading from practice.lp
Solving...
Answer: 1
removed(y1) removed(y2)
SATISFIABLE

Models       : 1
Calls        : 1
Time         : 0.035s (Solving: 0.00s 1st Model: 0.00s Unsat: 0.00s)
CPU Time     : 0.029s
mohitmehndiratta@x86_64-apple-darwin13 Self_Study %
```

   From this output, we can see that y1 and y2 (yellow) cubes are removed.

3. Show the ones which are not removed:

   The output below, shows all the cubes which are not removed.

   Output:



   From this output, we can see that all the cubes except the “yellow” were not removed.