**EXAM OF FUNDAMENTALS OF AI – FIRST MODULE**

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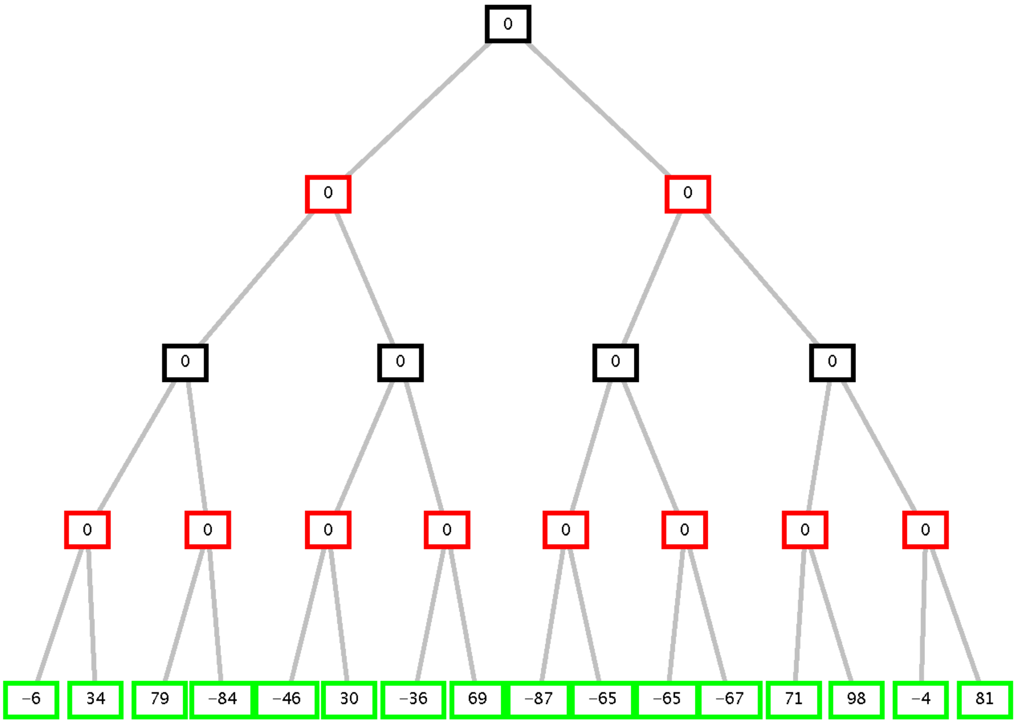
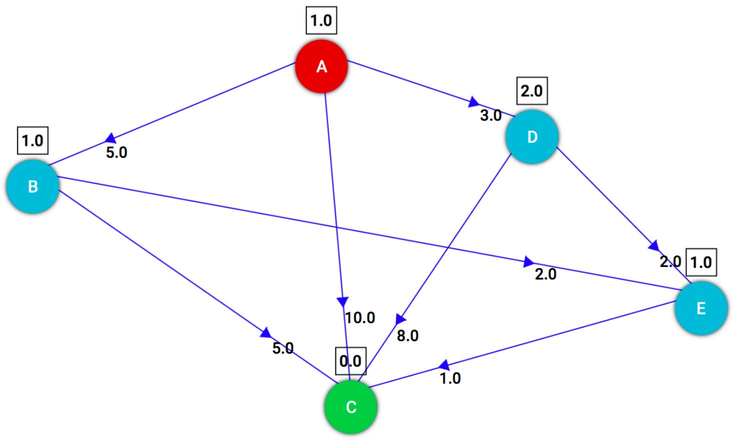
### Exercise 1

Consider the following game tree where the first player is *MAX*. Show how the *min-max* algorithm works and show the *alfa-beta* cuts. Also, show which is the proposed move for the first player.




### Exercise 2

Consider the following graph, where A is the starting node and C the goal node. The number on each arc is the cost of the operator for the move. Close to each node there is the heuristic evaluation of the node itself, namely its estimated distance from the goal:




a) Apply the depth-first search, and draw the developed search tree indicating for each node n the cost g(n) and the expansion order; in case of non-determinism, choose the nodes to be expanded according to the alphabetical order.
b) Apply the A* search, and draw the developed search tree indicating for each node n the function f(n) and the expansion order. In the case of non-determinism, choose the nodes to be expanded according to the alphabetical order. Consider as heuristic h(n) the one indicated in the square next to each node in the figure, that is:

h (A) = 1, h (B) = 1, h (D) = 2, h (E) = 1, h (C) = 0. Is the heuristic h defined in this way admissible?

What advantage is obtained by applying A*, compared to the outcome of the depth-first search?

**Exercise 3**

Consider the following CSP:

| | |
|---|---|
| X1 :: [0..2] | X1 * 10 + X2 <= 29 |
| X2 :: [0..9] | X1 * 10 + X2> = 1 |
| X3 :: [1..10] | X1 = (1 + X3) mod 10 |
| X2 = (1 + X3) div 10 | |

Apply the Arc-consistency to the CSP, checking the constraints for each arc, up to retirement, and show the final domains of the three variables.

**Exercise 4**

Given the following initial state **[at(room1), have_charge, handempty]**: and actions modeled as follows:

**vacuuming(room)**
PRECOND: have_charge, at(room), have_vacuum_cleaner
DELETE: have_battery
ADD: vacuumed(room)

**putdown_vacuum_cleaner**
PRECOND: have_vacuum_cleaner
DELETE: have_vacuum_cleaner
ADD: handempty

**pickup_vacuum_cleaner**
PRECOND: handempty
DELETE: handempty
ADD: have_vacuum_cleaner

**charge_battery**
PRECOND: not have_charge
DELETE: -
ADD have_charge

**go(room1, room2)**
PRECOND: at(room1)
DELETE: at(room1)
ADD at(room2)

and the following goal **vacuumed(room1), vacuumed(room2)**

Solve the problem by using the POP algorithm showing threats and how to solve them.

**Exercise 5**

1) Model the action **vacuuming** (preconditions, effects and frame axioms), and the initial state of the exercise 4 using the Kowalsky formulation

2) Show two levels of graph plan when applied to exercise 4.

3) What are the main features of a swarm intelligence algorithm?

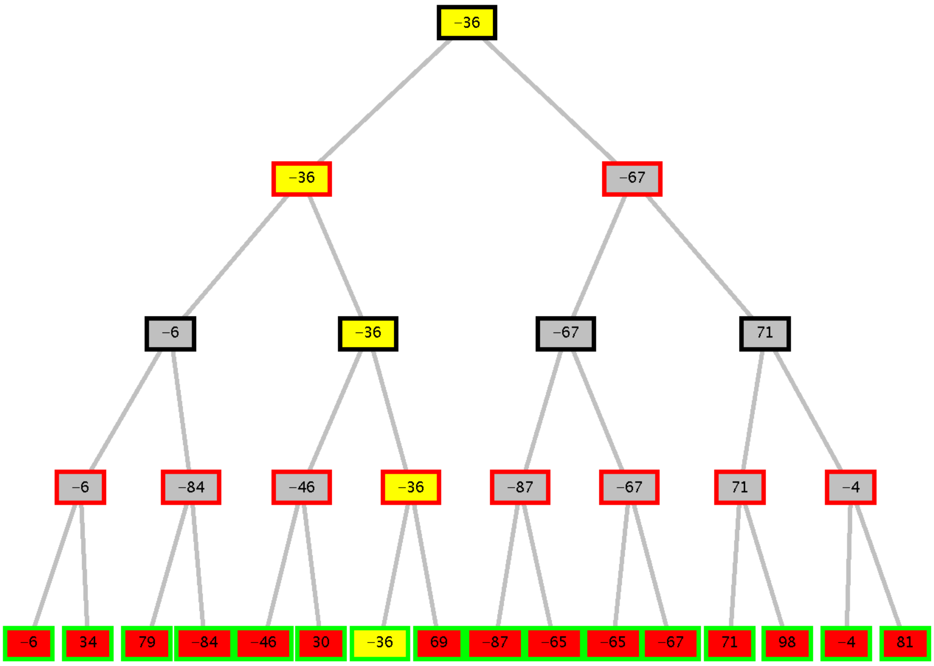
4) What is conditional planning and which are its main features?

5) What is modal truth criterion and why it has been defined.

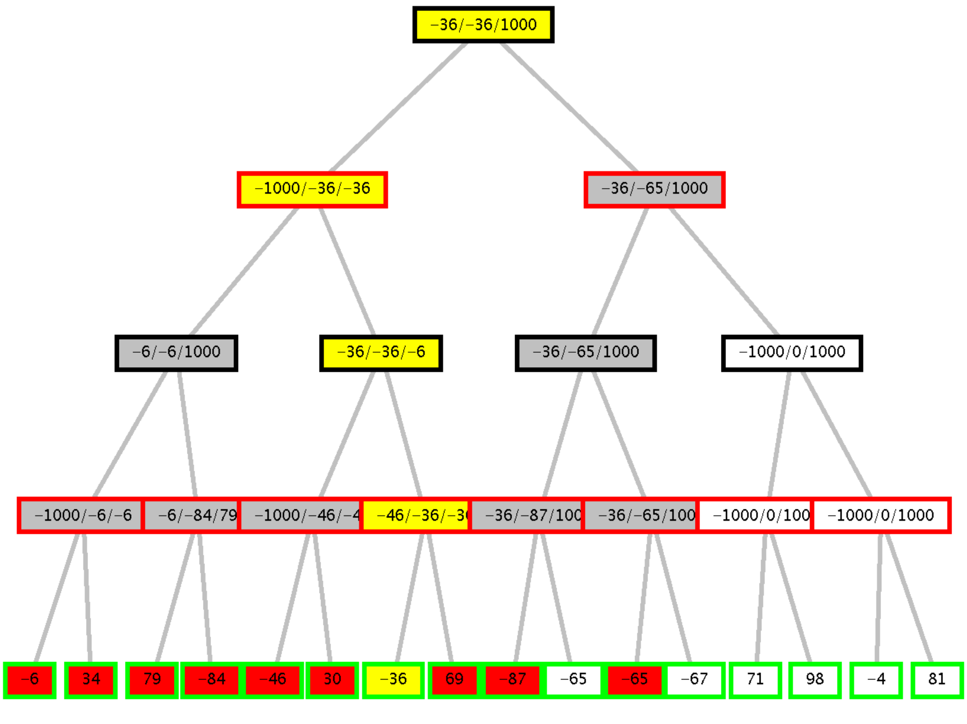
**Solution**

**Exercise 1**

Min-max

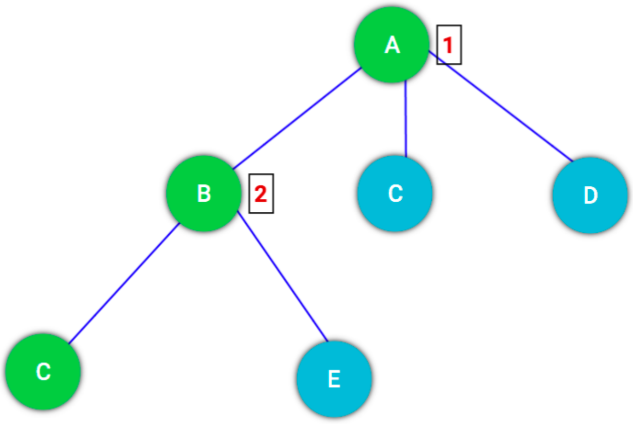



Alfa-beta :

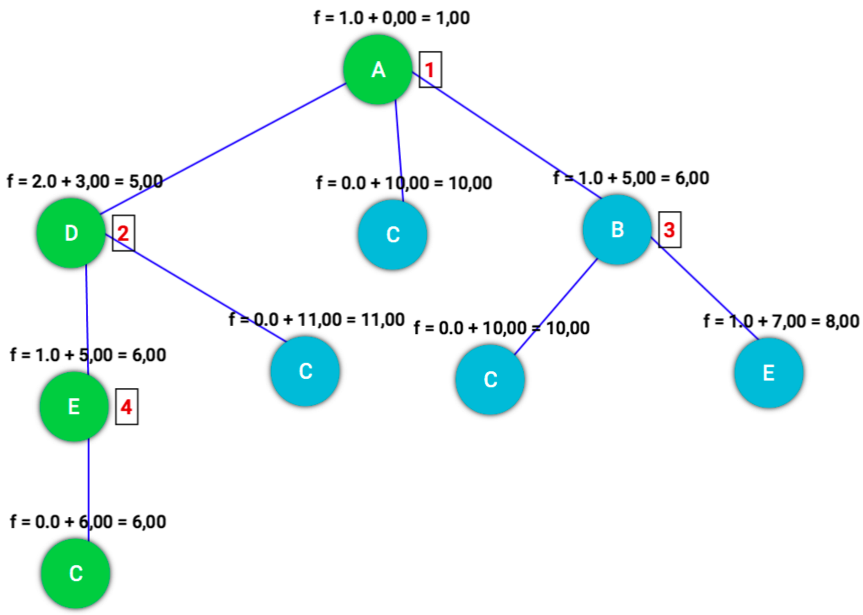


**Exercise 2**

Depth-first




Cost of path found (in green), ABC equal to 10.




With A*, path cost found (in green) - ADEC equal to 6 (optimal path)
Heuristic admissible.

**Exercise 3**

Applicando l'Arc-consistenza al CSP ottenuto, controllando i vincoli per ciascun arco, nei due sensi, si riduce il dominio delle variabili come segue:
X1::[0..2]

X2::[0,1]
X3::[1,9,10]

Ragionamento applicato:
Domini iniziali:
X1::[0..2]
X2::[0..9]
X3::[1..10]
Vincoli:
a) X1*10+X2 <=29
b) X1*10+X2 >=1
c) X1= (1+X3) mod 10 d) X2= (1+X3) div 10
Prima iterazione
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Applico (a).
Per ogni X1, esiste un X2? Si, domini untouched.
Per ogni X2, esiste X1? Si, domini untouched.
Applico (b)
Per ogni X1, esiste un X2? Si, domini untouched.
Per ogni X2, esiste X1? Si, domini untouched.
Applico (c).
Per ogni X1, esiste un X3? Si, domini untouched.
Per ogni X3, esiste un X1? Gli unici valori compatibili di X3 coi domini esistenti ti X1 sono: 1, 9, 10.
Nuovi domini:
X1::[0..2]
X2::[0..9]
X3::[1,9,10]
Applico (d).
Per ogni X2, esiste un X3? Gli unici valori compatibili di X2 sono: 0, 1.
Nuovi domini:
X1::[0..2]
X2::[0,1]
X3::[1,9,10]
Per ogni X3, esiste un X2? Si, domini untouched.
Seconda iterazione (perché nella prima i domini sono stati modificati)
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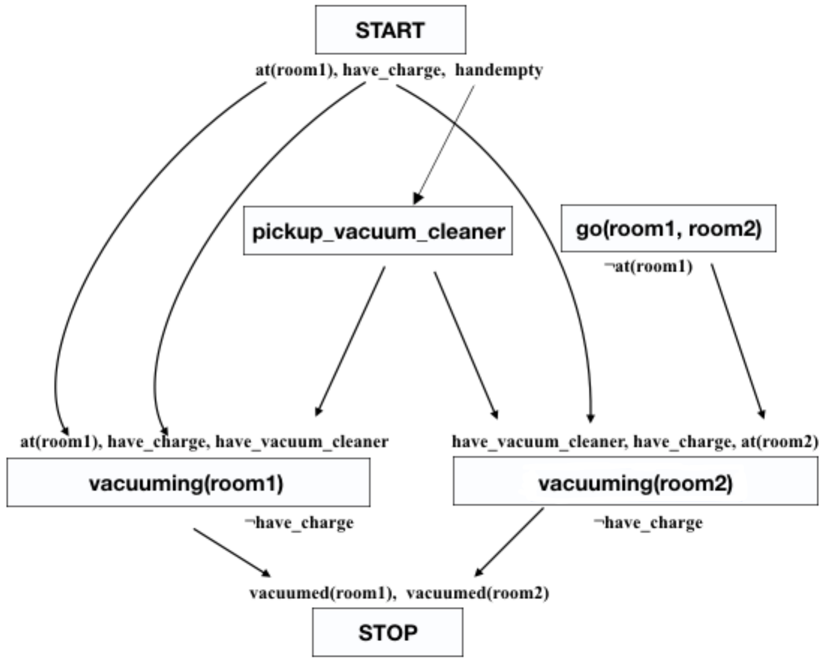
Applico (a):
X1*10+X2 <=29 Per ogni X1, esiste un X2? Si, domini untouched.
Per ogni X2, esiste X1? Si, domini untouched.
Applico (b):
X1*10+X2 >=1 Per ogni X1, esiste un X2? Si, domini untouched.
Per ogni X2, esiste X1? Si, domini untouched.
Applico (c):
X1= (1+X3) mod 10 Per ogni X1, esiste un X3? Si, domini untouched.
Per ogni X3, esiste un X1? Si, domini untouched.
Applico (d):
X2= (1+X3) div 10
Per ogni X2, esiste un X3? Si, domini untouched.
Per ogni X3, esiste un X1? Si, domini untouched.
Quiescienza. I domini finali quindi sono:
X1::[0..2]
X2::[0,1]
**X3::[1,9,10]**

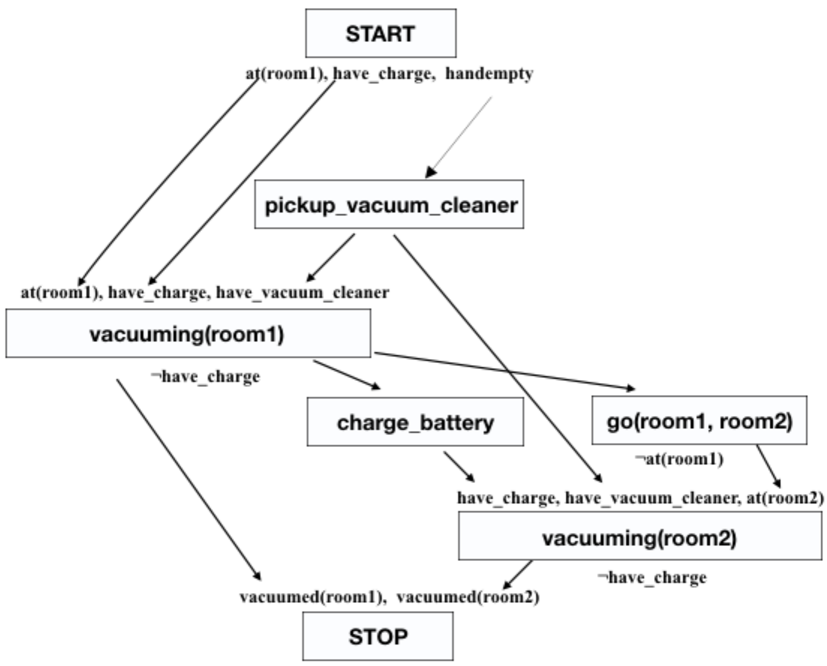
**Exercise 4**




The plan up to now contains threats. In particular:
<Start, vacuuming(room2), have_charge> and <Start, vacuuming(room1), have_charge> are threatened by vacuuming(room1) and vacuuming(room2) respectively. No ordering constraints can solve these threats: we need to insert a white knight charge_battery.

In addition the action go(room1, room2) threats causal link <Start, vacuuming(room1), at(room1)>

In this case demotion can solve the threat. We introduce an ordering constraint between vacuuming(room1) and go(room1, room2).



Note that we have to remove the causal link between the start and the

vacuuming(room2) for have charge and insert the new causal link between charge_battery and vacuuming(room2) for have_charge.

**Exercise 5**

**1)**

holds(at(room1),s0).
holds(have_charge, s0).
holds( handempty,s0).
holds(vacuumed(room), do(vacuuming(room),S))
pact(vacuuming(roomn),S):- holds(have_charge, S), holds(at(room),S), holds(have_vacuuming_cleaner,S).
*holds(V,do(vacuuming*(room),S*)):- holds(V,S), V\=have_charge.*

**2)**