INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Date: 29-08-2018 Time: *45 min* Full marks: 35 No. of students: 177
Autumn Semester Class Test 1, 2018 Dept: *Comp. Sc & Engg.* Sub No: CS60045
Elective Course Sub Name: ***Artificial Intelligence***
Instructions: ***Answer all four questions on the question paper.***

SOLUTION KEY

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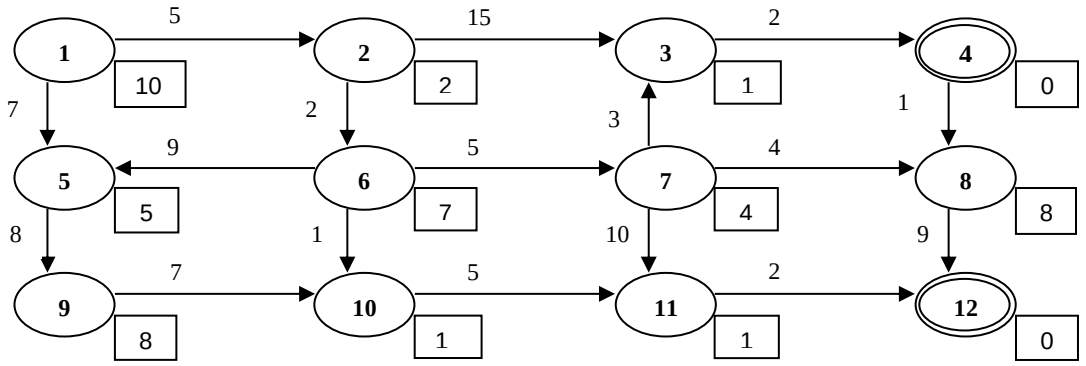
1. You are given two *admissible* heuristic functions $h_1(n)$ and $h_2(n)$ for use with the A* algorithm. From the following list identify all the heuristic functions that are guaranteed to be admissible. Write **Yes** in the boxes for admissible ones and **No** in the boxes for inadmissible ones.

[3 marks]

(a) $h_1(n) + h_2(n)$ | No | (b) $| h_1(n) - h_2(n) |$ | Yes | (c) $\max(h_1(n),h_2(n))$ | Yes |

2. Consider the following state space graph, where State-**1** is the starting state. Transition costs are shown besides the edges, and the heuristic estimate, *h(n)* of the cost of reaching a goal from a state n is shown in a box beside each state n. The states 4 and 12 are goal states.

[4 + 4 = 8 marks]



(a) On executing Algorithm A* on the above state space, the order in which nodes are expanded (selected from OPEN and moved into CLOSED) until the first goal is selected for expansion is:

1 , 2 , 5 , 6 ,10 , 11 , 12

(b) If you observe carefully, the path to the first goal that A* finds is non-optimal. This happens when the heuristic function at one or more nodes has a problem. Identify a node whose heuristic value is responsible in this case to cause A* to find the non-optimal path. For the same node, indicate the range of heuristic values, for which A* will find the optimal cost path to a goal.

The Path is optimal. There was a mistake in printing the heuristic value for node 10 (It should have been 10, not 1). Therefore, this question will not be evaluated, and 4 marks will be allotted to all.

3. Logic and Deduction:
   A. For each of the following statements, encode them in First Order Logic using the following predicates

owns(x, y):	x owns y
bookLover(x):	x is a book lover
burns(x, y):	x burns y
book(x):	x is a book
kindle(x):	x is a kindle

      A. Tom owns a kindle.
      B. Every kindle owner loves books.
      C. No book lover burns books.
      D. Either Tom or Austin burned the book called Origin.
      E. Every kindle is a book.

Solution:

S1: $\exists x$ owns (Tom, x) $\wedge$ kindle(x)

S2: $\forall x \forall y$ owns(x, y, kindle(y)) $\rightarrow$ bookLover(x)

$\neg$kindle(y) $\vee \neg$owns(x, y) $\vee$ bookLover(x)

S3: $\forall x \forall y$ (bookLover(x) $\wedge$ book(y)) $\rightarrow \neg$burns(x, y)

$\neg$bookLover(x) $\vee \neg$book(y) $\vee \neg$burns(x, y)

S4: book(Origin)

burns(Tom, Origin) $\vee$ burns(Austin, Origin)

S5: $\forall x$ kindle(x) $\rightarrow$ book(x)

$\neg$kindle(x) $\vee$ book(x)

   B. Normalize the first order logic statements from Q3.A and convert them to clause form. Clearly specify the clauses that you get and consistently label each of them with labels C1, C2 etc.

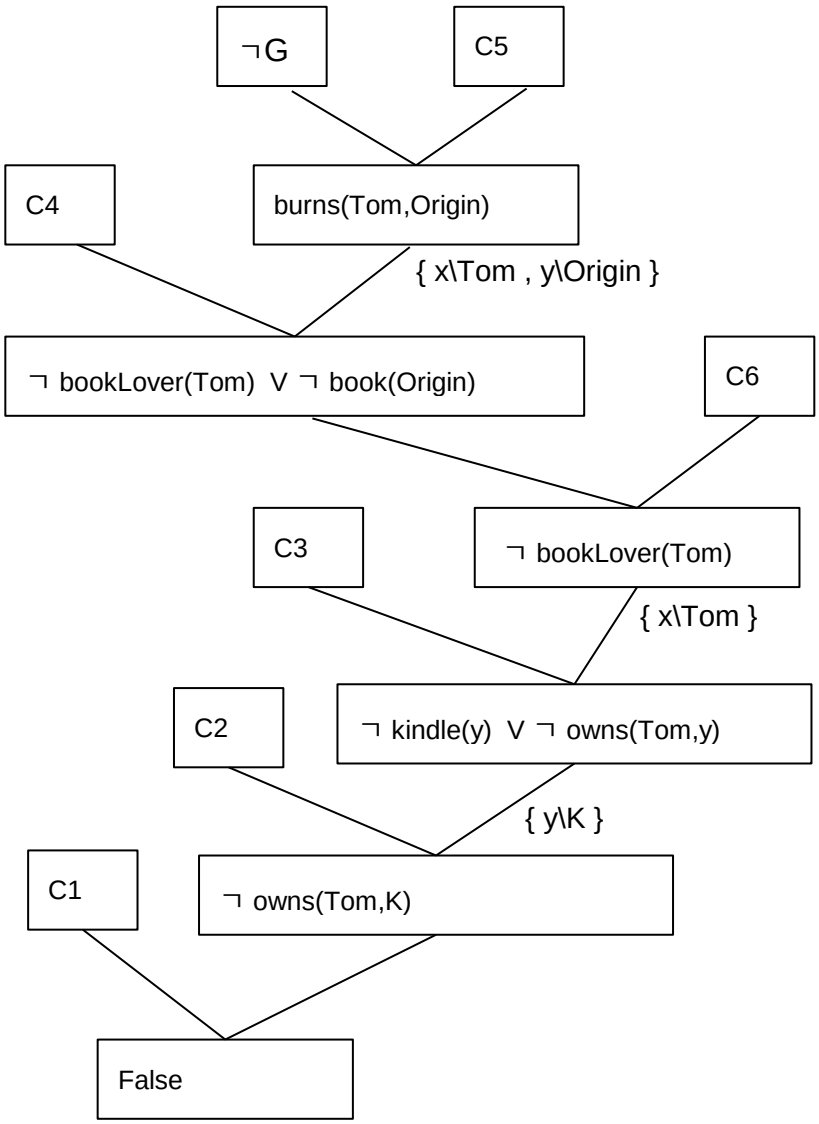
Solution:

C1: owns(Tom, k)
C2: kindle(k)
C3: $\neg$kindle(y) $\vee \neg$owns(x, y) $\vee$ bookLover(x)
C4: $\neg$bookLover(x) $\vee \neg$book(x) $\vee \neg$burns(x, y)
C5: burns(Tom, Origin) $\vee$ burns(Austin, Origin)
C6: book(Origin)
C7: $\neg$kindle(x) $\vee$ book(x)

C. Using the clauses from Q3.B, use resolution-refutation to answer the query: “Did Austin burn the Origin”?

[5 + 5 + 5 = 15 marks]

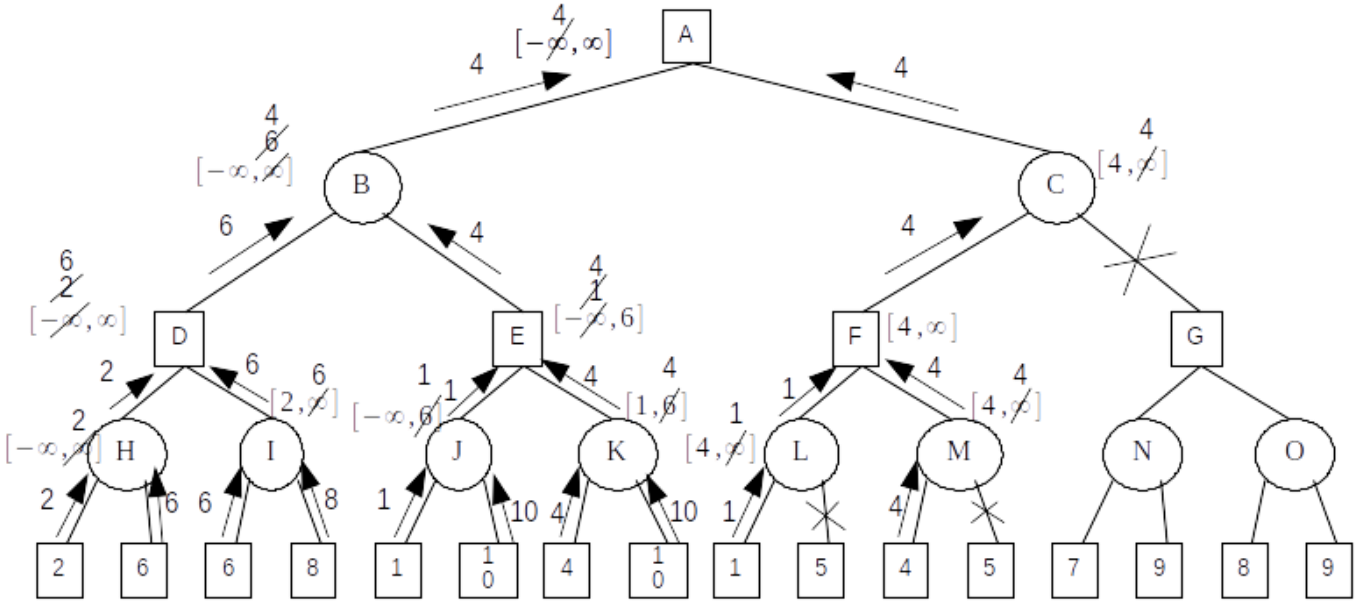
Solution: G: burns(Austin,Origin)



Therefore, Austin burned the origin.

4. In the game tree shown below, the square nodes are MAX nodes and the circular nodes are MIN nodes. Use the ⟨®-pruning algorithm on this tree (assuming that the traversal chooses the left branch first).

   A. On the tree, show the value returned by each node to its parent beside the corresponding branch. Cross out the edges which may be pruned.



   B. Populate the table below with the final values of ⟨ and ® at each node which is expanded. Ignore the rows corresponding to nodes which are not expanded.

Solution:

Node	Final α	Final β
A	4	∞
B	−∞	4
C	4	4
D	6	∞
E	4	6

Node	Final α	Final β
F	4	∞
G	-	-
H	−∞	2
I	2	6
J	−∞	1

Node	Final α	Final β
K	1	4
L	4	1
M	4	4
N	-	-
O	-	-

[4 + 5 = 9 marks]