Name:	ID#:	PIN:

CSE 4308 / CSE 5360 - *Artificial Intelligence I*

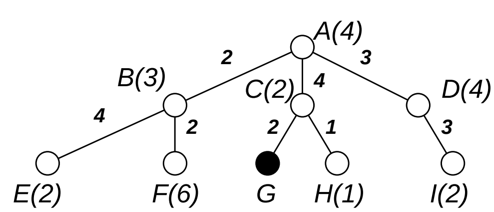
Final Exam - Fall 2001

Closed book, closed notes

Date: Dec. 13 2001, 2:00 pm - 4:30 pm

Problems marked with a * are required only for students in the graduate section (CSE 5360), but will be graded for extra credit for students of CSE 4308.

1. For the following tree, show the lists of *open* and *visited* nodes (with their associated costs) for each cycle of the listed search algorithms. The goal node is G, the numbers next to the edges indicate the associated cost, and the numbers in parentheses next to the nodes are their heuristic values. Ties should be broken alphabetically. (For the *visited* list it is sufficient to list only the nodes that are added in each cycle.) (12 / 12 points)

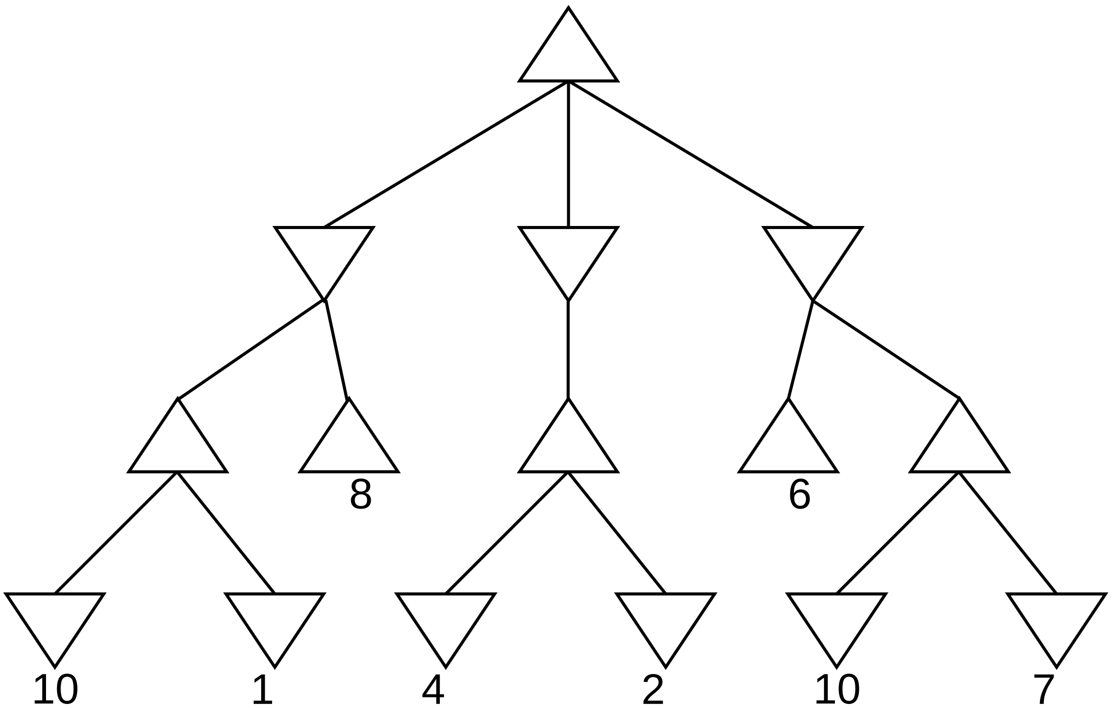


a) Depth-first search:

b) Uniform cost search:

c) A^* search:

2. Perform minimax search with alpha-beta pruning for the following game trees. Indicate which branches are pruned (assuming that the search visits nodes from left to right). Also indicate next to each node either its true value or its α or β value. The utilities of terminal nodes are again indicated below the leaf nodes. (10 / 8 points)



3. Transform the following sentences into implicative normal form. (10 / 8 points)

   a) $P(Mary) \wedge \exists x(Q(x) \Rightarrow R(x, Mary))$

   b) $\forall x(\exists y(P(x) \wedge \neg(Q(x) \Rightarrow R(x, y)) \vee \forall x \neg Q(x)))$

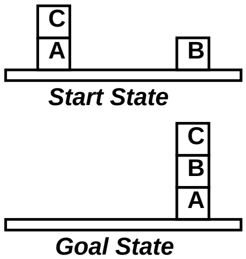
4. Use resolution with refutation to show that the following queries can be inferred from the given knowledge base. At each resolution step also indicate the corresponding unifier. (10 / 10 points)

$$
\begin{aligned}
KB: \quad & S_1: \quad R(A,B) \\
& S_2: \quad P(A) \\
& S_3: \quad Q(A,A) \\
& S_4: \quad P(B) \\
& S_5: \quad P(x_1) \wedge Q(x_1,y_1) \Rightarrow R(y_1,x_1) \\
& S_6: \quad Q(x_2,y_2) \wedge R(y_2,z_2) \Rightarrow Q(x_2,z_2) \\
& S_7: \quad P(x_3) \wedge Q(x_3,y_3) \Rightarrow R(y_3,B)
\end{aligned}
$$

a) $R(B,A)$

b) $R(B,B)$

5. Construct a partial order plan for the following blocks-world problem. (You can show the plan as a graph containing the causal links, ordering constraints, and the preconditions of the operations). (12 / 12 points)



$OP(ACTION:\ Move(b,x,y),$
$\quad PRECOND:\ On(b,x) \wedge Clear(b) \wedge Clear(y),$
$\quad EFFECT:\ On(b,y) \wedge Clear(x) \wedge \neg On(b,x) \wedge \neg Clear(y))$

$OP(ACTION:\ MoveToTable(b,x),$
$\quad PRECOND:\ On(b,x) \wedge Clear(b),$
$\quad EFFECT:\ On(b,Table) \wedge Clear(x) \wedge \neg On(b,x))$

6. Give the initial state description (in predicate calculus) and STRIPS-style definitions for the actions in the following navigation problem. (Each action schema has to contain at least the obvious preconditions and effects. (10 / 8 points)

   In this domain, a robot can move between four rooms (A, B, C, $andD$) and empty trash cans. The goal is to empty all the trash. To do this, the robot can *move* to a specific room, *search* for the trash can, and *empty* it. To empty a trash can, the robot has to be in the same room and must have already found it (there is a trash can in every room). To find a trash can, the robot has to be in the same room.

   Initially the robot is in room A.

7. Construct a conditional plan for the following, modified shopping problem. In this problem, a product may not be available in a store and there is an additional sensing operation that determines if a product is available. Your plan should reflect that your agent always prefers to buy a product in the supermarket (SM), even if it does not know if it is available. (You can show the plan as a graph containing the causal links, the ordering constraints, the preconditions of the operations, and the context of each operation.) (12 / 12 points)

   $OP(ACTION: \ Go(x, y),$
   $\quad PRECOND: \ At(x),$
   $\quad EFFECT: \ At(y))$

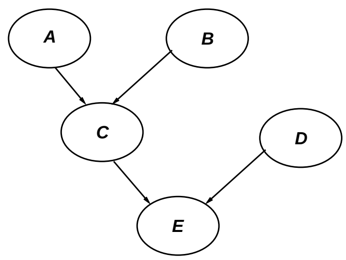
   $OP(ACTION: \ Buy(b, x),$
   $\quad PRECOND: \ At(x) \wedge Sells(x, b),$
   $\quad EFFECT: \ Have(b))$

   $OP(ACTION: \ CheckAvailability(b),$
   $\quad PRECOND: \ At(x),$
   $\quad EFFECT: \ KnowsWhether(\text{“}Sells(x, b)'')$)

   Start: $At(Home) \wedge \neg Have(Milk) \wedge \neg Have(Cookies) \wedge Sells(SM, Cookies) \wedge Sells(CS, Cookies) \wedge Sells(CS, Milk)$

   Goal: $At(Home) \wedge Have(Milk) \wedge Have(Cookies)$

8. Use the following probabilistic network and conditional probabilities to compute the conditional probabilities of D under the given conditions. (12 / 12 points)



C : $P(C \mid A \wedge B) = 0.5$
$P(C \mid \neg A \wedge B) = 0.5$
$P(C \mid A \wedge \neg B) = 0.1$
$P(C \mid \neg A \wedge \neg B) = 0.2$

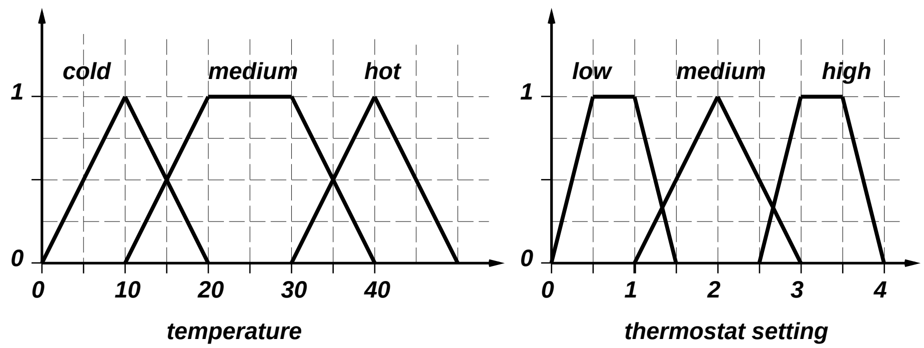
E : $P(E \mid C \wedge D) = 0.1$
$P(E \mid \neg C \wedge D) = 0.5$
$P(E \mid C \wedge \neg D) = 0.1$
$P(E \mid \neg C \wedge \neg D) = 0.1$

a) $P(E \mid A \wedge B \wedge D)$

b) $P(E \mid \neg A \wedge \neg B \wedge \neg D)$

c) $P(E \mid A \wedge \neg B \wedge D)$

9. A Fuzzy logic control system is used to regulate the setting of a thermostat. The thermostat setting depends on the temperature and is controlled by three fuzzy rules. The control system uses two linguistic variables ($temperature$ and $thermostat\ setting$). Each of these can belong to three possible sets ($cold$, $medium$, and hot for $temperature$ - low, $medium$, and $high$ for $thermostat\ setting$). The following are the corresponding membership functions:



The controller uses the following fuzzy rules:

if $temperature$ is $cold$ then $thermostat\ setting$ is $high$
if $temperature$ is $medium$ then $thermostat\ setting$ is $medium$
if $temperature$ is hot then $temperature\ setting$ is low

Calculate the resulting thermostat settings for the following temperatures using a Mamdani inference system (i.e. $\mu_{A \vee B} = max(\mu_A, \mu_B)$, $\mu_{A \wedge B} = min(\mu_A, \mu_B)$, and coupled implication $A \rightarrow B = A \wedge B$). Show the membership function for the thermostat setting derived from the three rules and the actual setting resulting from defuzzification. (12 / 12 points)

a) $temperature = 15$

b) $temperature = 25$

b) $temperature = 35$

10.* Construct a multi-layer network with step function units (perceptron units) for a three-input parity function. Give the connections in the network and a set of weights that compute the parity function. (+6 / 6 points)