CIS604: Techniques in Artificial Intelligence

Midterm Examination, Fall 2013

Duration: 75 minutes

October 23, 2013

Instructions:

- This is a closed-book exam.
- Answer *all* questions.
- Start with the easy questions, and don't spend too much time on one question until you covered the others.
- If you feel unsure of an answer, you might want to explain a bit further.
- If you are caught cheating, you will be asked to leave and will receive 0 for this exam.

Student Name: –

Student ID: –

Problem	Points Obtained	Points Possible
1		
2		
3		
4		
5		
6		
Total		

1 Search - General

1. How does randomized hill-climbing choose the next move each time?
   (a) It generates a random move from the succesors of the current state, and accepts this move.
   (b) It generates a random move from the whole state space, and accepts this move.
   (c) It generates a random move from the succesors of the current state, and accepts this move only if this move improves the evaluation function.
   (d) It generates a random move from the whole state space, and accepts this move only if this move improves the evaluation function.
2. Which of the following is the main reason of pruning a Minimax search?
   (a) To avoid infinite branches
   (b) To save computational cost
   (c) To guarantee optimality
3. In the worst case, what is the number of nodes that will be visited by Breadth-First Search in a (non-looping) tree with depth m and branching factor b?
4. Uniform Cost Search can be thought of as a special case of $A*$.
5. Depth-first search always expands at least as many nodes as $A*$ search with an admissible heuristic.

Solution:

1. c)
2. b)
3. O(b^m)
4. True
5. False; a lucky DFS might expand exactly m nodes to reach the goal.

2 Admissability

2.1

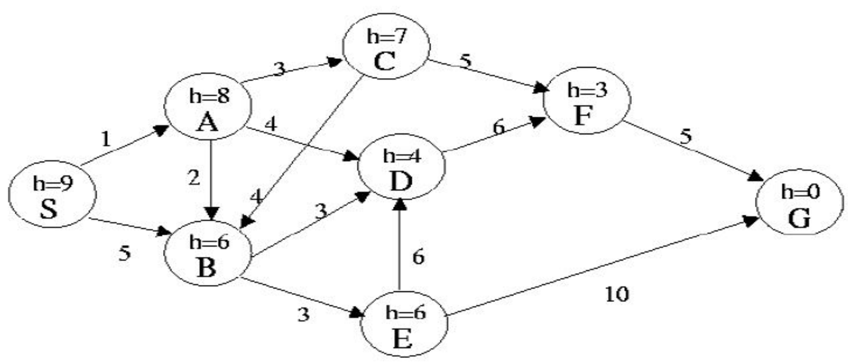
Consider a version of the Pacman World with tunnels, i.e. where pacman in a single action can enter at one position and reappear on another predefined non-adjacent position, possibly closer to the goal. Would the Manhattan distance still be admissable? Would the Euclidian distance still be admissable?

2.2

Consider a version of the Pacman World, where pacman is capable of going to adjacent diagonal fields. Would the Manhattan distance still be admissable? Would the Euclidian distance still be admissable?
Solution:
Tunnel Pacman:
No
No

Diagonal
No
Yes

3 Search - Applied



In this problem the start state is S, and the goal state is G. The transition costs are next to the edges, and the heuristic estimate, h, of the distance from the state to the goal is in the states node. Assume ties are always broken by choosing the state which comes first alphabetically.

1. What is the order of states expanded using Depth First Search? Assume DFS terminates as soon as it reaches the goal state.

2. What is the order of states expanded using Breadth First Search?

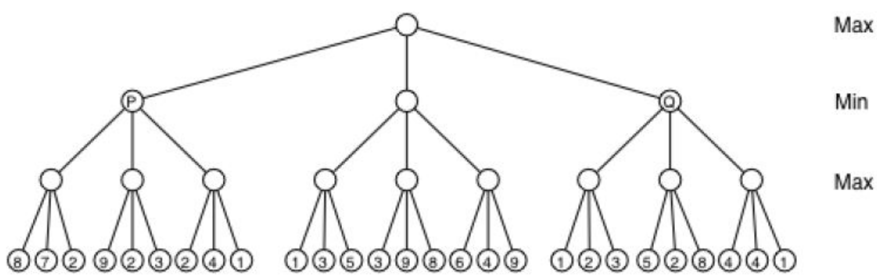
3. What is the order of states expanded using A* search?

4. What is a least cost path from S to G?

Solution:
1) S, A, B, D, F ,G
2) S, A, B, C, D, E, F, G
3) S, A, B, D, C, E, F, G
4) S, A, C, F, G

4 Game Trees

The figure below is the game tree of a two-player game; the first player is the maximizer and the second player is the minimizer. Use the tree to answer the following questions:



1. What is the final value of this game?

2. Is the final value of beta at the root node (after all children have been visited) $+\infty$?

3. What is the final value of beta at the node labeled P (after all of P's children have been visited)?

4. Will any nodes be pruned?

5. What value will Q return to its parent?

Solution:

1. 5, which can be determined from a quick application of the minimax algorithm.

2. True. The root node is a maximizing node, and the value of beta never changes at a maximizing node.

3. Since we are at a minimizing node and alpha is negative infinity, beta will take on the smallest value returned by any of Ps children. In this case, Ps children would return 8, 9, and 4, so the final value of beta at P will be 4. Suppose we are in the middle of running the algorithm. The algorithm has just reached the node labeled Q. The value of alpha is 5 and the value of beta is $+\infty$.

4. Yes. If we work out the algorithm on the leftmost subtree of Q, we see that it returns a value of 3. Beta at Q will then become 3, and 3 is less than the alpha value at Q, so Q will immediately return a value to its parent. This means that the other two subtrees of Q are pruned.

5. Since its beta value after visiting the leftmost subtree was less than its alpha value of 5, Q will return its alpha value of 5.

5 Propositional Logic

5.1

Let p, q, and r be the following propositions:

- p: You get an A on the final exam
- q: You do every exercise in the book.
- r: You get an A in this class.

Write the following formulas using p, q, and r and logical connectives.

1. You get an A in this class, but you do not do every exercise in the book.

2. To get an A in this class, it is necessary for you to get an A on the final.

3. Getting an A on the final and doing every exercise in the book is sufficient for getting an A in this class.

Solution:
1) $r \wedge \neg q$.
2) $r \rightarrow p$.
3) $p \wedge q \rightarrow r$

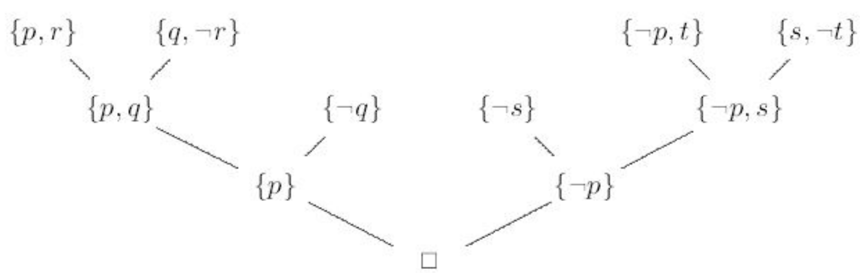
Procedure for converting to CNF

1. Use equivalence $(A \leftrightarrow B) \equiv (A \rightarrow B) \wedge (B \rightarrow A)$ to eliminate $\leftrightarrow$
2. User equivalence $A \rightarrow B \equiv \neg A \vee B$ to eliminate $\rightarrow$
3. Use De Morgan's laws
   $\neg(A \wedge B) \equiv \neg A \vee \neg B$ and
   $\neg(A \vee B) \equiv \neg A \wedge \neg B$
   to push $\neg$ immediately before propositions
4. Use equivalence $\neg\neg A \equiv A$ to eliminate double negation
5. Use the distributive law $A \vee (B \wedge C) \equiv (A \vee B) \wedge (A \vee C)$ to finalise the conversion

5.2

1. Convert the following propositional logic sentence to conjunctive normal form (CNF):
$$(R \rightarrow S) \rightarrow \neg(S \rightarrow Q)$$
2. Assuming the following formula, which is already in CNF,
$$(p \vee r) \wedge (q \vee \neg r) \wedge (\neg q) \wedge (\neg p \vee t) \wedge (s \vee \neg t)$$
prove s using resolution (assume $\neg s$ and derive a contradiction using the resolution rule).

Solution:
1) (R∨ S) ∧(R∨¬Q) ∧ (¬S∨¬Q) 2) To prove s, we assume that ¬s and derive a contradiction using the resolution rule. We therefore have the following: (p∨r)∧ (q ∨¬r)∧(¬q) ∧ (¬p∨t)∧ (s∨¬t) ∧ (¬s) We can apply resolution over these clauses as follows:



Since we could produce an empty clause (i.e. a contradiction $\perp$), we conclude that ¬s cannot hold, and therefore s must be true.

5.3

Determine whether each of the following is a tautology, a contradiction or neither.

1. $$(p \rightarrow q) \wedge (\neg p \vee q)$$

2. $$(p \vee q) \leftrightarrow (q \vee p)$$

3. $$(\neg p \wedge q) \wedge (p \vee \neg q)$$

4. $$(p \rightarrow \neg q) \vee (\neg r \rightarrow p)$$

Solution:
1) neither
2) tautology
3) contradiction
4) tautology

6 First Order Logic

Consider the Forward Chaining algorithm for First Order Logic (see Figure). Also assume the following Knowledge Base KB:

function FOL-FC-ASK(KB, α) **returns** a substitution or *false*
  inputs: KB, the knowledge base, a set of first-order definite clauses
        α, the query, an atomic sentence
  local variables: new, the new sentences inferred on each iteration

  repeat until new is empty
    $new \leftarrow \{ \}$
    for each $rule$ **in** KB **do**
      $(p_1 \wedge \ldots \wedge p_n \Rightarrow q) \leftarrow$ STANDARDIZE-VARIABLES(*rule*)
      for each θ such that SUBST($\theta, p_1 \wedge \ldots \wedge p_n$) = SUBST($\theta, p'_1 \wedge \ldots \wedge p'_n$)
            for some $p'_1, \ldots, p'_n$ in KB
        $q' \leftarrow$ SUBST(θ, q)
        if q' does not unify with some sentence already in KB or new **then**
          add q' to new
          $\phi \leftarrow$ UNIFY(q', α)
          if ϕ is not *fail* **then return** ϕ
    add new to KB
  return *false*

$$American(x) \land Weapon(y) \land Sells(x, y, z) \land Hostile(z) \rightarrow Criminal(x)$$
$$Weapon(M_1)$$
$$Weapon(M_2)$$
$$Hostile(Nono)$$
$$Sells(West, v, Nono)$$
$$American(West)$$
$$American(John)$$

Imagine the Forward Chaining algorithm has been invoked with FOL-FC-Ask$(KB, Criminal(X))$.
Starting from the marked position (circle), explain the rest of the algorithm until termination. Describe the values of the variables $rule$, $p_1 \ldots p_n$, $p'_1 \ldots p'_n$, θ q' and ϕ.