COMP 131 Answers to Midterm 1 – October 8, 2008

Name:

Marks				
Q.1 (25)	**Q.2 (20)**	**Q.3 (15)**	**Q.4 (40)**	**Total (100)**

You have 75 minutes to answer 4 questions. Questions are weighted differently, and their point values are specified next to them. Each question has easier and harder parts, so try to answer at least the easier parts of all questions.

Open book, open notes, slides, homework assignments.

There are seven pages in this exam. Please write your answers in the space provided. The last page is a tear-off with all the figures for question 1, for your convenience. You don't need to hand it in.

Question 1 – Search – 25 points

Look at figure on the last page (tear the page off to have the figures in front of you as you answer). The directed graph in the figure represents a problem that was solved with four different search algorithms. For each of the search trees in the figure (5 points per tree), say which algorithm was used, out of this list: Depth-Fist Search, Breadth-First Search, Iterative Deepening DFS, Uniform Cost Search, Best-First (greedy) Search, A*.

Assume that:

- Children of a node are expanded in alphabetical order.
- Ties in expanding are also broken according to alphabetical order.
- In every tree, all the nodes shown were added to the fringe at some point during execution.
- The numbers next to nodes correspond to the "score" that the algorithm assigned to them.
- The goal node found is highlighted.

Specify also whether a heuristic was used, and if so, whether it was heuristic H1 or H2 (defined next to the graph on the figure), and whether the search found the optimal path to the goal. Write your answers in the space provided.

search tree 1:
Heuristic function, if any?
Optimal path? Why or why not?

Answers: *Breadth-FirstSearch, no heuristic function is used. No, BFS returns the first path found, it could be any path.*

search tree 2:
Heuristic function, if any?
Optimal path? Why or why not?

Answers: *A^*, H_2 is used for the heuristic function. If the heuristic function is admissible and consistent, it always returns the optimal path, H_2 is admissible and consistent, so the optimal path is found.*

search tree 3:
Heuristic function, if any?
Optimal path? Why or why not?

Answers: *Uniform-cost search, no heuristic function is used. It always returns the optimal path.*

search tree 4:
Heuristic function, if any?
Optimal path? Why or why not?

Answers: *Depth-First Search, no heuristic function is used. It is not the optimal path, because DFS returns the first path it finds, it could be any path.*

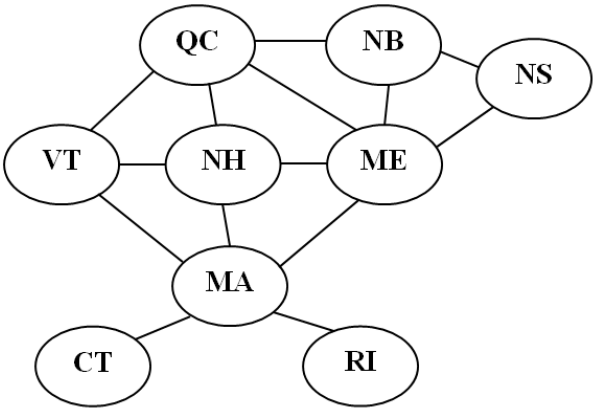
Are heuristics H1 and H2 equally good for this problem? Explain why. Be specific. (5 points)

Answer: *No. H_1 is admissible but inconsistent. H_2 is admissible and consistent. So H_2 is preferable, because it will return optimal paths found by A^*.*

Question 2 – Constraint Satisfaction – 20 points

The American Geographic Society decided to produce a combined map of New England and bordering Canadian provinces. The map must use only the colors Red, Blue, and Green. Additionally, Quebec must be colored Blue to reflect the color of its flag. And Vermont must be colored Green to underscore the fact that it's the Green Mountain State.

You have been hired as a CSP specialist to see if these constraints can be satisfied.



1. (5 points) Write the **initial domain** (before any constraint propagation) of all the variables for this problem.

QC	NB	NS	VT	NH	ME	MA	CT	RI
$\{B\}$	$\{R, G, B\}$	$\{G\}$	$\{R, G, B\}$	$\{R, G, B\}$	$\{R, G, B\}$	$\{R, G, B\}$	$\{R, G, B\}$	$\{R, G, B\}$

2. (10 points) With backtracking search and forward checking, what heuristic(s) will you use to pick the order of variables to which you try to assign values? Give the resulting ordered chain of variables and their possible values. How many solutions does this problem have?

   Answers: *MRV (aka most constrained variable) is the most important heuristic here. You can use the degree heuristic or least constraining value* ***in addition to*** *MRV. Example order (others are possible):* $QC = B \rightarrow VT = G \rightarrow NH = R \rightarrow MA = B \rightarrow ME = G \rightarrow NB = R \rightarrow NS = B \rightarrow$ $RI = \{B, G\},\ CT = \{B, G\}$.

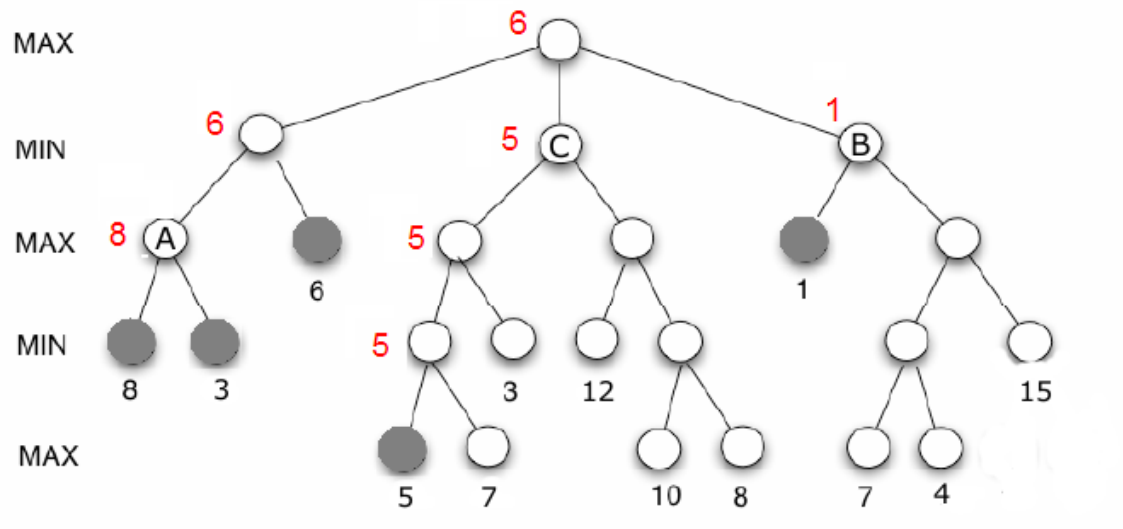
   As drawn, this problem has 4 possible solutions, since CT and RI can independently both be either Blue or Green. However, since CT and RI border on a real map of New England, no points were taken off for saying there are only 2 solutions (sorry for the confusion!).

3. (5 points) Is it possible to improve on your heuristics by using arc consistency, for this particular problem? Explain how or why not.

   Answers: *Forward checking (removing values from connected variables' domains when a new variable is assigned) with the MRV and possibly degree heuristic already does the best job on this problem.* AC *can't give any more reduction on search space.*

Question 3 – Games – 15 points

A two-player zero-sum game:



1. (5 points) What is the minimax value of these nodes?

   A: 8

   B: 1

   C: 5

2. (10 points) On the figure above, clearly indicate with a checkmark inside every node that is evaluated by the minimax algorithm with alpha-beta pruning. Do not put any marks in nodes that are not evaluated (because they're pruned). To help us give you partial credit, write the alpha and beta values next to evaluated nodes.

   Answers: *Assume standard minimax search, from left to right, as shown above.*

Question 4 – Logic and Inference – 40 points

You decided to write an automatic book recommender for your online bookstore. Its recommendations will be based on the users' recent purchases. This is what you know about the authors of the books you sell and your users' tastes:

Philip K. Dick writes science fiction and is the author of "The Penultimate Truth" and "Solar Lottery". Neil Gaiman wrote books called "Good Omens" and "American Gods". He writes fantasy. Everybody who likes fantasy also likes science fiction. If someone bought a book, they will like it. They will also like books in the same genre. If a user will like a book, you want to recommend it. Mary, a new user, has just purchased "Solar Lottery".

1. (5 points) Translate the above paragraph into statements in first-order logic. Use any connectives and quantifiers, but only these predicates:
   Author(x,y) – x is the author of book y
   Likes(x,y) – x likes book y
   Bought(x,y) – x bought book y
   SciFi(x) – x is a book of science fiction
   Fantasy(x) – x is a book of fantasy
   Recommend(x,y) – I will recommend book x to user y

   Answers: *Here we use the abbreviations PKD for Philip K. Dick, PT for "The Penultimate Truth", SL for "Solar Lottery", and NG for Neil Gaiman, GO for "Good Omens" and AG for "American Gods". The paragraph can be translated as:*

   $\forall x.\ Author(PKD, x) \rightarrow SciFi(x)$
   $Author(PKD, PT) \wedge Author(PKD, SL)$
   $Author(NG, GO) \wedge Author(NG, AG)$
   $\forall x.\ Author(NG, x) \rightarrow Fantasy(x)$
   $\forall x, y, z.\ Likes(x, y) \wedge Fantasy(y) \wedge SciFi(z) \rightarrow Likes(x, z)$
   $\forall x, y.\ Bought(x, y) \rightarrow Likes(x, y)$
   $\forall x, y, z.\ Bought(x, y) \wedge Fantasy(y) \wedge Fantasy(z) \rightarrow Likes(x, z)$
   $\forall x, y, z.\ Bought(x, y) \wedge SciFi(y) \wedge SciFi(z) \rightarrow Likes(x, z)$
   $\forall x, y.\ Likes(x, y) \rightarrow Recommend(y, x)$
   $Bought(Mary, SL)$

2. (5 points) Rewrite your knowledge base from **1** in definite clauses (Horn form).

step	formula
1	Author(PKD,PT)
2	Author(PKD,SL)
3	Author(NG,GO)
4	Author(NG,AG)
5	Bought(Mary, SL)
6	$\neg$ Author(PKD,x) $\vee$ SciFi(x)
7	$\neg$ Author(NG, y) $\vee$ Fantasy(y)
8	$\neg$ Likes(x, y) $\vee\neg$ Fantasy(y) $\vee\neg$ SciFi(z) $\vee$ Likes(x, z)
9	$\neg$ Bought(x, y) $\vee$ Likes(x, y)
10	$\neg$ Bought(x, y) $\vee\neg$ Fantasy(y) $\vee\neg$ Fantasy(z)$\vee$ Likes(x, z)
11	$\neg$ Bought(x, y) $\vee\neg$ SciFi(y) $\vee\neg$ SciFi(z) $\vee$ Likes(x, z)
12	$\neg$ Likes(x, y)$\vee$ Recommend(y, x)

Horn form (definite clauses) means: only disjunctions allowed in each clause, at most one literal is non-negated, there are no quantifiers. Facts that were part of conjunctions need to be stated separately.

Knowing that you will need to put your KB into Horn form was a clue for part 1 to make your FOL statements into either facts or implications with universally quantified variables.

3. (12 points) Your automated recommender uses forward chaining (with unification) to find books to recommend to the new user Mary. Give all the steps in the inference process, until you run out of books to recommend. Start by writing the KB query in logical form. There may be more lines than you need.

step no.	steps used	substitution	result
13	query	–	Recommend(b, Mary)
14	1 & 6	x/PT	SciFi(PT)
15	2 & 6	x/SL	SciFi(SL)
16	3 & 7	x/GO	Fantasy(GO)
17	4 & 7	x/AG	Fantasy(AG)
18	5 & 9	x/SL, y/SL	Likes(Mary, SL)
19	[11,5,14,15]	x/Mary, y/SL, z/PT	Likes(Mary, PT)
20	12 & 18	x/Mary, y/SL	Recommend(SL, Mary)
21	12 & 19	x/Mary, y/PT	Recommend(PT, Mary)

Forward chaining starts from the facts of the KB and applies any rule (in order of appearance in the KB) all of whose premises unify with facts.

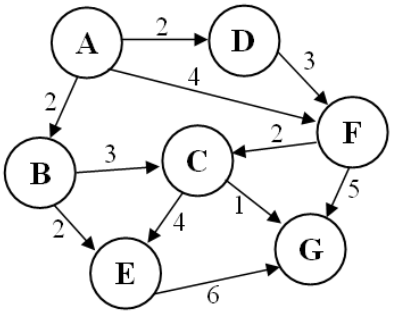
4. (12 points) How would your steps look if you wanted to use backward chaining instead, starting with "The Penultimate Truth" as a candidate for recommendation? Would basic backward chaining prove you can recommend this book to Mary? If so, how (show the steps). If not, explain specifically why not and show the first few steps to demonstrate.

step no.	steps used	substitution	result (pushed onto stack of goals)
13	query	–	Recommend(PT, Mary)
14	13 & 12	x/Mary, y/PT	Likes(Mary, PT)
15	14 & 8	x/Mary, z/PT	¬Likes(Mary,y), ¬Fantasy(y), ¬SciFi(PT)
16	[15:1] & 8	y/Mary	¬Likes(Mary,y), ¬Fantasy(y), ¬SciFi(z)
17	[16:1] & 8	x/Mary	$\cdots$ Infinite Loop!(DFS)

Basic backward chaining, when applying the rules from 2 in the order given, will get stuck in an infinite loop trying to satisfy the first antecedent of rule 8: $\neg Likes(Mary, y)$.

5. (6 points) Based on your knowledge base, should you be recommending "Good Omens" to Mary? Will your automated inference engine necessarily arrive at the same answer to this question that you gave? Explain specifically why.
Answer: *No, you should not recommend "Good Omens" to Mary, as there is no such rule or sequence of rules. Specifically, we know that everybody who likes fantasy also likes sci-fi, but not necessarily the other way round. The relationship is an implication, not an equivalence.*
Automatic inference will not always conclude that a query is not satisfiable, because the problem is semi-decidable. However, for this KB, forwarding chaining will stop and fail at step 21 above after it runs out of clauses to unify, which is equivalent to saying that "Good Omens" will not be recommended.

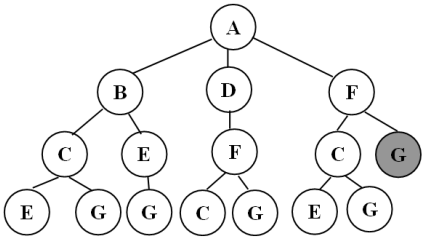
Figure 1: Question 1 – Search: graph, heuristics, and search trees.



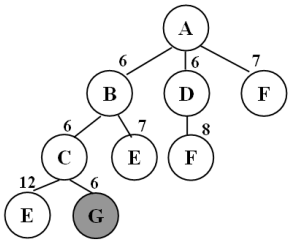
Question 1 graph

	H1	H2
A	4	4
B	4	4
C	1	1
D	1	4
E	3	3
F	3	3
G	0	0

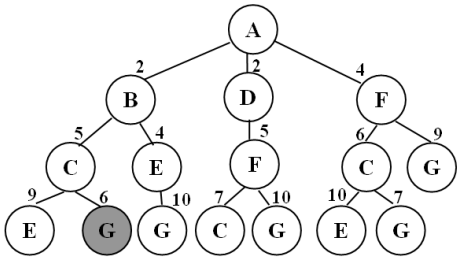
Heuristic functions



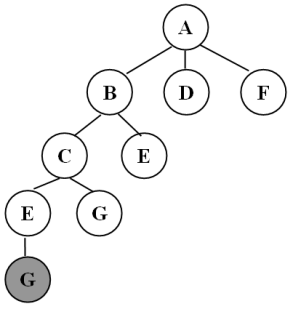
search tree 1



search tree 2



search tree 3



search tree 4