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Computer Science and Engineering 250A
Introduction to Artificial Intelligence

March 21, 1997

FINAL EXAM

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO START!!!!

-Please DO NOT put your name at the top of each page.

-The exam is closed book.

-!!!SHOW ALL WORK!!!

-There are 6 problems: Make sure you have all of them -
AFTER I TELL YOU TO START!

-Read each question carefully.

-Remain calm at all times!

Problem	Type	Points	Score
1	Search & Game playing	30	
2	Logic	25	
3	Probability	15	
4	Planning	20	
5	More Planning	30	
6	Belief Networks	25	
	Total	145	

Search & Game playing (30 pts)

1. (a) (15 pts; 2pts/each) Briefly define the following concepts:

Bi-directional search

Greedy search

informedness, as in A1 is more informed than A2.

the horizon problem

admissibility

Explain what each of the three terms of the following expression stand for (1 pt each):

f(n) = g(n) + h(n)

Which part of the right hand side corresponds to *domain specific* knowledge? (2 pts again)

Search & Game playing (CONTINUED)

(b) (9 pts) The following search tree has letter labels on the nodes and a heuristic evaluation number on each one (please ignore the fact that these don't make much sense in terms of path cost, just use these numbers - don't add anything together!). Note that two nodes are labeled **G** - these are goal nodes at which the search will terminate. Using the search tree, write down the letter labels of the nodes in the order they would be taken *off* the OPEN list by:

(i) Depth first search

(ii) IDA*

(iii) Best-first search

(c) (6 pts) *Beam search* is a type of Breadth-First Search using the f evaluation function in which only the n best nodes at each level are expanded, where n is some small, user-defined number. Assuming that f is admissible, the answer is at depth d, and the branching factor of the tree is b ($\geq n$), what is the time and space required by beam search? Is it optimal? Complete?

Logic (25 pts)

2. (a) (6 pts) Convert the following predicate calculus representation of "Every student has some course that he hates" to clause form. I use S, H, C to represent the predicates, "[]" shows the scope of the forall, "{}" shows the scope of the EXISTS). *Be careful in the first step!* Make sure you end up with ALL students!

FORALL x [S(x) → (EXISTS y { C(y) & H(x,y) })]

(b) (4 pts) Try to unify each of the following. For each one, *show the substitution* if they are unifiable, or *state why they are not unifiable* if they aren't.

[Big hint: Only ONE is unifiable!]

i) {P(x), P(f(x))}

ii) {P(y,f(x)), P(f(a),y)}

iii) {P(x,y), P(y,f(x))}

iv) {P(a), P(f(x))}

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2.(c) (15 pts) Resolution can act like LISP: we let *cons(x,y)* denote the list formed by inserting element *x* at the head of list *y*. We denote the empty list by NIL. Thus, the list (2,3) is denoted cons(2(cons(3,NIL))).

The following axioms describe LAST(x,y), which is intended to mean that *y* is the last element of the list *x*.

1. FORALL u [LAST(cons(u,NIL), u)].

2. FORALL x,y,z [LAST(y,z) -> LAST(cons(x,y),z)].

Prove the following theorem using resolution refutation proof:

EXISTS v [LAST(cons(2,cons(1,NIL)),v)].

(points will be awarded for converting to clause form, properly negating the goal, and finally, doing the proof. Be sure to SHOW your substitutions at each step!)

Probability (15 pts)

3. (a)(10 pts) Using the following probabilities and Bayes' rule, compute the probability that John has lung cancer given that he has a bad cough, and the probability that John has pneumonia given that he has a bad cough.

L = John has lung cancer
N = John has Pneumonia
C = John has a bad cough

$P(L) = .0001$
$P(N) = .01$
$P(C|L) = .9$
$P(C|N) = .9$

Bayes' rule:

$$P(H|E) = \frac{P(E|H) * P(H)}{P(E)}$$

You may assume the frequency of coughs (P(C)) in the population is .5 (half the people are coughing all the time!).

Show your work!

(b) (5 pts) How did your estimate of whether he has these diseases change as a function of the evidence? Write the Bayes rule above in such a way as to emphasize the Bayesian updating step.

Planning (20 points)

4. (a) (5 pts) What is the distinction between linear and nonlinear as applied to planning systems?

(b) (10 pts) Explain why the following example of a blocks world problem is *not* an example of the "Sussman Anomaly".

(c) (5 pts) Can you change the goals so that this *is* an example of the Sussman anomaly?

More Planning (30 pts)

5. The Monkey & Bananas problem: There is a monkey in a room with some bananas hanging out of reach from the ceiling, but a box is available that will enable the monkey to reach the bananas if he climbs on it. Initially, the monkey is at A, the bananas at B, and the box at C. The monkey and the box have height *low*, but if the monkey climbs onto the box he will have height *high*, the same as the bananas. The actions available to the monkey include *Go(?x,?y)* from place ?*x* to place ?*y*, *Push(?object, ?x, ?y)*, which pushes object ?*object* from ?*x* to ?*y*, *Climb(?object)* to climb onto an object and *Grab(?object)*. Grabbing results in holding an object if the monkey and the object are at the same place at the same height.

(a) (3 pts) Write down the initial state in predicate calculus.

(b) (12 pts) Write down the four operators in book-like (or classroom-like) notation, providing at least the obvious preconditions and effects. [CONTINUED NEXT PAGE]

(c) (15 pts) Solve the problem (with goal Hold(bananas)) using the POP algorithm from the text. Feel free to select subgoals to avoid backtracking. Below the plan, list the steps you are taking, described in English (e.g. "3. select action A to achieve precondition P"). State when you are resolving threats, if any. Be sure to show both causal links, and ordering links (that are not already causal links).

Belief Networks (25 points)

(a) (3 pts) What is the *key idea* that lead to the modern resurgence in the use of belief networks?

(b) (3 pts) Explain what is wrong with the following statement: Although belief networks don't allow representation of the complete joint probability, which would require an exponential number of numbers, they are a good approximation that require many fewer numbers.

(c) (4 pts) Why is it important what order nodes are added to a belief network? What is the best method for doing so?

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(d) (15 points) (Problem 15.2 from R&N): In your local nuclear power station, there is an alarm that senses when a temperature gauge exceeds a certain threshold. The gauge measures the temperature of the core. Consider the Bollean variables A (alarms sounds), FA (alarm is faulty), FG (the gauge is faulty), and the multivalued nodes G (gauge reading) and T (actual core temperature).

i) (5 points) Draw a belief net for this domain, given the unhappy situation that the gauge is more likely to fail when the core temperature is high.

ii) (2 points)Is your network a polytree?

iii) (8 points) Suppose there are just two possible and actual measured temperatures, Normal and High; and that the gauge gives the incorrect temperature *x%* of the time when it is working, but *y%* of the time when it is faulty. Give the conditional probability table associated with G.