Computer Science Department
Stanford University
Comprehensive Examination in Artificial Intelligence
Autumn 1994

October 18, 1994

READ THIS FIRST!

1. You should write your answers for this part of the Comprehensive Examination in a BLUE BOOK. Be sure to write your MAGIC NUMBER on the cover of every blue book that you use.

2. Be sure you have all the pages of this exam. There are 4 pages.

3. This exam is OPEN BOOK. You may use notes, articles, or books—but no help from other sentient agents such as other humans or robots.

4. Show your work, since PARTIAL CREDIT will be given for incomplete answers. For example, you can get credit for making a reasonable start on a problem even if the idea doesn't work out; you can also get credit for realizing that certain approaches are incorrect. On a true/false question, you might get partial credit for explaining why *you* think something is true when *we* think it is actually false. But no partial credit can be given if you write nothing.

1. LOGIC and AUTOMATED REASONING [20 Points]

(a) i. Transform the following sentence into clausal form
$S : \forall x.\forall y.(P(x,y) \wedge Q(y,x)) \Rightarrow \forall x.\exists y.(R(x,y) \vee \forall z.S(y,z))$ [3 Points]

ii. In general, does the procedure that you use in part i above result in clauses that preserve the validity of a sentence?
Does it preserve the satisfiability of a sentence? [2 Points]

(b) Find a most general unifier for each of the following sets, if one exists; otherwise, explain why such a unifier does not exist. [6 Points]
(Assume that u, w, x, y, z are variables, A, B are constants, and f, g are function symbols.)

i. $\{P(x,y,z), P(w,u,y), P(u,A,u)\}$
ii. $\{P(z, f(x,y)), P(f(A,B), x)\}$
iii. $\{P(f(x,y,z)), P(f(g(y), f(z,A,B), g(A)))\}$

(c) Everyone is a skier or a mountain climber. All mountain climbers hate rain, and all skiers like snow. Mike likes everything that Tom does not like, and Tom likes everything that Mike does not like. Tom likes rain and snow. Therefore there is a mountain climber that is not a skier.

The clausal form for this set of sentences is the following:
(Assume that x is a variable, and Tom, $Mike$, $Rain$, and $Snow$ are constants.)

C_1. $\{Skier(x), Climber(x)\}$
C_2. $\{\neg Likes(x, Rain), \neg Climber(x)\}$
C_3. $\{\neg Skier(x), Likes(x, Snow)\}$
C_4. $\{\neg Likes(Mike, x), \neg Likes(Tom, x)\}$
C_5. $\{Likes(Mike, x), Likes(Tom, x)\}$
C_6. $\{Likes(Tom, Rain)\}$
C_7. $\{Likes(Tom, Snow)\}$
C_8. $\{\neg Climber(x), Skier(x)\}$

Use resolution with set of support to derive the empty clause, where $\{C_8\}$ is the set of support. [9 Points]

2. LEARNING

15 Points

(a) Consider the problem of concept formation in books in a book store. The specific relations for the books are

- type (which can be an element of { fiction, non-fiction }),
- binding (which can be an element of { Paperback, Hardcover }), and
- subject (which can be an element of { AI, Geology, Air-Travel }).

Our language restricts the space of possible concepts to be conjunctions of positive literals.

The following instances are in the target set (i.e. are positive instances)

	SPHERE	GÖDEL-ESCHER-BACH	LFAI
TYPE:	FICTION	NON-FICTION	NON-FICTION
BINDING:	PAPERBACK	PAPERBACK	PAPERBACK
SUBJECT:	AI	AI	AI

The following instances are not in the target set (i.e. are negative instances)

	Terminal Man	AIRPORT
TYPE:	FICTION	NON-FICTION
BINDING:	HARDCOVER	PAPERBACK
SUBJECT:	AI	AIR-TRAVEL

i. What is the version graph for the target set? [5 Points]

ii. What are the most general and the most specific concepts consistent with this set? [4 Points]

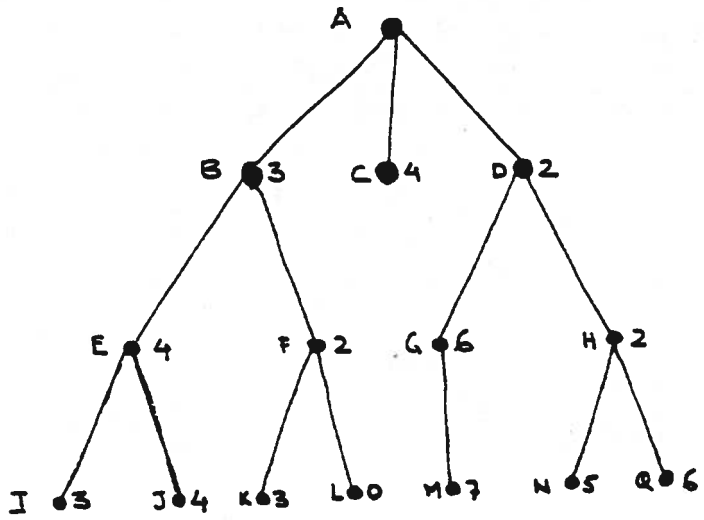
(b) Find the smallest decision tree to represent the concept

$(P_1(x) \wedge P_2(x)) \vee (P_3(x) \wedge P_4(x) \wedge P_5(x))$ [6 Points]

3. SEARCH

15 Points

(a) Consider the following search space:



List the order in which nodes are visited in the tree above for each of the following search strategies. The values next to the node labels represent the (heuristic) cost to get to the goal node, arc traversal is a unit cost operation, and L is the goal node.

i. A* Search. [6 Points]

ii. IDA* Search (assuming an initial depth cutoff of 1). [5 Points]

(b) Briefly explain the differences between hill climbing and best-first search. [4 Points]

4. PROBABILISTIC REASONING [10 Points]

Consider the three sentences, H: John's car battery is low, E_1: John has difficulty starting his car, E_2: John's car has dimmed headlights. Suppose $p(E_1|H) = 0.8$. $p(E_1|\neg H) = 0.2$. $p(E_2|H) = 0.75$. $p(E_2|\neg H) = 0.6$, and $p(H) = 0.1$.

Assume the Odds of an event A given B to be

$O(A|B) = p(A|B)/p(\neg A|B)$

(a) What are the odds that John's car battery is low given that he has difficulty starting his car? [5 Points]

(b) What are the odds that John's car battery is low given that he has difficulty starting his car *and* has dimmed headlights? (for this part assume that given H (or $\neg H$). E_1 and E_2 are independent.) [5 Points]