2001 Comprehensive Examination
Artificial Intelligence

1. Search. (20 points) Consider a search tree with uniform branching factor b and depth d, and consider a search problem for which there is a single solution in the tree at depth k. A solution at the root of the tree is depth 0. Give expressions for the worst case cost of finding the solution, in terms of nodes visited, for (a) breadth-first search, (b) depth-first search, and (c) iterative deepening (starting at depth 0 and incrementing by 1 on each iteration. Give closed form expressions, if you can; but sums are okay. If you are unable to do this problem in general, you can still get some points by answering the question for the special case of b=2. And, if that is still too daunting, you may be able to scrape out a point or two by fixing k and d as well.

2. Automated Reasoning. (30 points) Two questions related to resolution.

(a) Consider the following pairs of expressions. u, v, w, x, y, z are variables; all other letters are constants. For each pair, say whether or not they are unifiable; if the answer is yes, give the most general unifier.

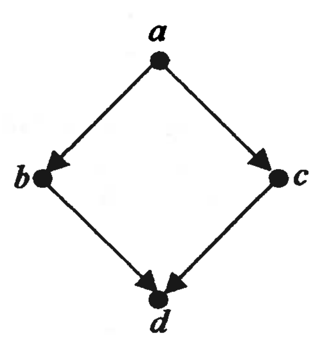
$$p(x,b) \text{ and } p(f(y,y),y)$$
$$q(x,f(y,a),g(g(x))) \text{ and } q(z,f(z,u),y)$$

(b) Given the following premises, use the resolution method to prove $\neg p(c,a)$.

$$\forall y.\ \forall z.(p(y,z) \Rightarrow \neg p(z,y))$$
$$\forall x.(p(b,x) \Rightarrow p(a,x))$$
$$p(b,c) \vee p(a,c)$$

Note that this is a question about the resolution method. You will get zero points for proving it in any other way.

3. Probability. (30 points) Adapted from Nilsson's *Artificial Intelligence: A New Synthesis*. The admissions committee for a major university wants to know the probability that an applicant is qualified given that the person is admitted. It has the belief network shown below.



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$p(a)=0.5$
$p(b|a)=1$
$p(b|\neg a)=0.5$
$p(c|a)=1$
$p(c|\neg a)=0.5$
$p(d|b,c)=1$
$p(d|b, \neg c)=0.5$
$p(d|\neg b,c)=0.5$
$p(d|\neg b, \neg c)=0$

a - applicant is qualified
b - applicant has a high grade point average
c - applicant has a high graduate record examination score
d - applicant is admitted

What is the probability that an admitted student is qualified? In other words, calculate $p(a|d)$.

4. Natural Language. (20 points) Consider the augmented phrase structure grammar shown below.

S(r(x, z) ∧ r(y, z)) → Q(r(both(x,y), z))
Q(w(u, v)) → NP(u) Verb(w) NP(v)
NP(x) → Noun(x)
NP(both(x, y)) → NP(x) ***and*** *NP(y)*
Noun(tom) → ***Tom***
Noun(dick) → ***Dick***
Noun(harry) → ***Harry***
Noun(mary) → ***Mary***
Verb(hates) → ***hate***
Verb(hates) → ***hates***

(a) Given that *s* is the top-level non-terminal, is there a semantic interpretation for the expression ***Mary hates Tom and Harry***? If so, what is it?

(b) Given that *s* is the top-level non-terminal, is there a semantic interpretation for the expression ***Tom and Harry hate Mary***? If so, what is it?

(c) Change the augmentations on the existing rules to eliminate ungrammatical sentences like ***Tom and Harry hates Mary*** (without eliminating the corresponding grammatical sentences). If you are unable to do this, you can still get partial credit by changing the rules themselves.

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