Doctoral Exam in Artificial Intelligence
December 1995

Problem 1:
Consider the following sentences:

i. All the people in room 101 are either professors or students.

ii. If a student is in room 101, then some advisor of his is also in room 101.

iii. The advisor of any student is a professor.

iv. Someone is in room 101.

v. Some professor is in room 101.

Let $\mathcal{L}$ be a first-order language containing the following predicates.

p(X) — X is a professor.
s(X) — X is a student.
a(X,Y) — X advises Y.
r(X) — X is in room 101.

A. (10 points) State each of the sentences (i) – (v) in $\mathcal{L}$.

B. (10 points) Show that (v) can be proven from (i) – (iv) using resolution.

C. (5 points) Is this a Horn theory? Explain.

Problem 2: (10 points)
You are given the problem of determining whether a set of formulas in the propositional calculus, such as

$p \vee q \vee \neg r.$
$(\neg p \wedge q) \Leftrightarrow r.$
$p \Rightarrow \neg(q \Rightarrow r).$
...

is consistent. Describe how you could use state-space search to solve this problem. What are the states? What are the operators? What kind of search technique should you use?

Problem 3: (15 points)
Back propagation in neural networks may be considered as an instance of hill climbing. Explain how. What is the space being searched? What is the objective function being minimized? How is the direction of motion computed?

Problem 4: (15 points)
Consider a program doing inductive learning of a concept c(X). The program's current definition of c(X) is the formula

$$c(X) \Leftrightarrow [\exists_Y\ p(X,Y) \wedge q(f(X),Y)]$$

where the predicates p and q and the function f are assumed to be known. For each of the following, state whether it is a generalization of the above definition, a specialization, or neither.

A. $c(X) \Leftrightarrow \exists_Y\ p(X,Y)$.

B. $c(X) \Leftrightarrow [p(X,f(X)) \wedge q(f(X),f(X))]$.

C. $c(X) \Leftrightarrow [\exists_Y\ p(a,Y) \wedge q(f(a),Y)]$. (a is a constant.)

D. $c(X) \Leftrightarrow [\forall_Y\ p(X,Y) \wedge q(f(X),Y)]$.

E. $c(X) \Leftrightarrow [\forall_Y\ p(X,Y) \Rightarrow q(f(X),Y)]$.

Problem 5: (20 points)
Consider the following three sentence, each using the preposition "with".

i. I ate dessert with Mrs. Ginzberg. (= in company with Mrs. G)

ii. I ate dessert with enthusiasm. (= in an enthusiastic manner)

iii. I ate dessert with a spoon. (= using a spoon)

iv. I ate dessert with a cup of coffee (= in combination with coffee).

A. How could an AI program choose the correct meaning of "with"?

B. Why is it important that an AI program should distinguish between these meanings of "with"?

Problem 6: (15 points)
The TWEAK program works by applying operations to a partially specified plan. For each of the following, state whether or not it is used in TWEAK.

A. Add a step.

B. Delete a step.

C. Interchange the order of two steps.

D. Constrain one step to precede another.

E. Constrain two steps to be executed simultaneously.

F. Bind a variable to a constant.

G. Constrain two variables to be unequal.

H. Constrain two constants to be equal.

I. Add a universal quantifier.

J. Augment the addlist of an action.