Doctoral Exam in Artificial Intelligence
May 1996

Problem 1: (25 points)

Consider the following sentences:

i. Everyone is either male or female.

ii. A male child is a son.

iii. A female child is a daughter.

iv. Everyone in the room has a child.

v. Everyone in the room either has a son or has a daughter.

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

m(X) — X is male.
f(X) — X is female.
c(X,Y) — X is a child of Y.
s(X,Y) — X is a son of Y.
d(X,Y) — X is a daughter of Y.
r(X) — X is in the room.

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

B. Show that (v) can be proven from (i) – (iv) using resolution. You should show the Skolemized form of all the clauses involved and each step of the resolution proof. You need not show the intermediate steps of Skolemization.

Problem 2: (20 points)

One simple approach to planning is to use standard state space search, where a state is the set of all fluents true in a given situation and an operator is an action. For example, in the standard blocks world shown below, the state would be the set { on(a,table), on(b,a), clear(b), on(c,table), on(d,c), clear(d) }.

```
                B           D
                A           C
      ------------------------------  Table
```

Let N be the number of blocks in a given situation.

A. What is the maximal branching factor in this state space? What is the minimal branching factor?

B. What is the maximal distance (in terms of number of operators) between two states in the state space?

C. Give simple lower and upper bounds on the size of the state space.

D. Describe a simple admissable heuristic function for this state space.

Problem 3: (10 points) It is widely, though not universally, believed that the syntax of natural language is not best described in terms of a context-free grammar. Give examples of two features of English syntax that support this belief.

Problem 4: (10 points) Give an example to show that a machine-translation program must resolve syntactic ambiguities in the input text in order to produce a correct translation.

Problem 5: (10 points)

A. Construct a multi-layer, feed-forward neural network to carry out the following: There are four input cells. An input signal has an activation level of 1 or 0 at each input cell. We want the neural network to recognize signals with exactly two 1's and two 0's in input.

B. Prove that no single perceptron can carry out this task.

Problem 6: (25 points)

Consider the following variation on the blocks world. Blocks are rectangular and may be placed either vertically or horizontally. Blocks oriented the same way can be stacked, and a vertical block can be placed on top of a horizontal block, but a horizontal block cannot be placed on a vertical block. A block can be rotated to switch its orientation, but only if it is on the table and clear. As usual, the table has infinite capacity, and a block at the top of one stack can be moved to the top of another stack, as long as the orientations don't conflict.

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         ---
         | |
         | |   Vertical block A
         | |
    _____|_|____
    |__________|  Horizontal block B
```

A. How can this world be characterized in the STRIPS representation?

B. Show how STRIPS can solve the following problem: From the starting state shown above, attain the goal "on(B,A)".