

CS 540-1 -- Introduction to Artificial Intelligence

Exam 2 - November 4, 1992

CLOSED BOOK

90 minutes

Write your answers on these pages and show your work. If you feel that a question is not fully specified, state any assumptions you need to make in order to solve the problem. You may use the backs of these sheets for scratch work.

Write your name on this and all other pages of this exam. Make sure your exam contains eight problems on eight pages.

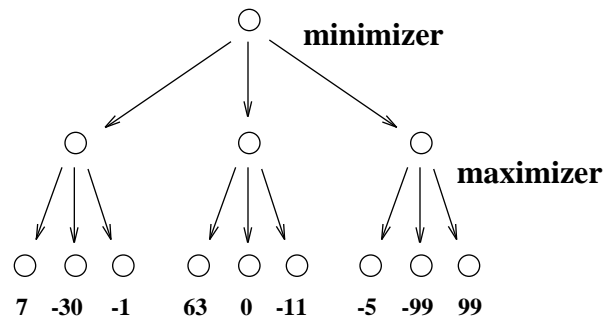
Name _____

Student ID _____

Problem	Score	Max Score
1	_____	5
2	_____	10
3	_____	12
4	_____	28
5	_____	15
6	_____	10
7	_____	15
8	_____	5
Total	_____	100

PROBLEM 1 - Alpha-Beta Pruning (5 points)

Consider the game tree shown below. We wish to use alpha-beta pruning to determine the best play for the *minimizer*. The numbers below the leaves of this tree indicate the scores that will be produced by the static board evaluator *if it is called*. Circle all the leaf nodes that must be evaluated during the alpha-beta procedure and circle the arc representing the minimizer's best move. Above the root node, write the score the minimizer can expect to achieve.

**PROBLEM 2 - Predicate Calculus (10 points)**

Give *one* predicate calculus representation for each of these English sentences. Choose reasonable constants, predicates and functions - the predicate *marys-mother-is-married-to-marys-father* is *not* an acceptable answer to the first question.

- a) *Mary's father is married to Mary's mother.*
- b) *No human enjoys golf.*
- c) *All professors except historians write programs.*
- d) *Some professor that is not a historian writes programs.*

PROBLEM 3 - Unification (12 points)

For each of the following pairs of predicate calculus statements determine their *most general unifier (mgu)*, if it exists. If none exists, write *FAIL* and briefly explain why. Write your answers on the lines provided. (Terms beginning with ?'s are universally-quantified variables.)

$(P\ ?x\ ?y\ (f\ ?w\ ?z))$ $(P\ I\ ?q\ (f\ ?a\ ?b\ ?c))$ _____

$(P\ (f\ ?x\ ?y)\ (g\ ?z))$ $(P\ (f\ (g\ a)\ ?a)\ (g\ a))$ _____

$(R\ (f\ ?x)\ ?z\ (g\ ?y))$ $(R\ ?y\ ?w\ (g\ (f\ a)))$ _____

$(R\ (f\ ?x\ ?y)\ (f\ ?y\ ?x))$ $(R\ ?z\ ?z)$ _____

$(Q\ ?x\ (g\ ?a\ ?a)\ ?b)$ $(Q\ (f\ ?y\ ?z)\ (g\ ?x\ ?b)\ (h\ (g\ ?z)))$ _____

PROBLEM 4 - Clause Form and Resolution (28 points)

- a) Convert the following *wff*'s to *clause form*. Write the clauses on the lines provided.

$$(a \rightarrow b) \wedge c$$

$$\neg [\forall x \forall y Q(x,y)]$$

$$\forall x \forall y \exists z [P(x,y,z) \wedge R(z,y,x)]$$

$$\exists y \forall x \exists z [P(x,y,z) \vee R(z,y,x)]$$

- b) Assume you wish to use resolution to prove the goal

$$\exists x [P(x,A) \vee Q(A,x)]$$

from the existing axioms in a resolution theorem prover. Convert the goal into the form necessary to attempt this. That is, write the clause(s) that need to be created from the goal and added to the theorem prover's existing collection of clauses. (Note: just write the new clauses, do not resolve with the clauses of part a.)

- c) Consider the following statements:

If an exam is easy, some students are happy.

If an exam contains a question on resolution, no students are happy.

If an exam contains a question on resolution, the exam is not easy.

Convert these sentences to first-order predicate calculus, and then use *resolution* to show that the third one follows from the first two. (Number your clauses. When you deduce a new clause, indicate which existing clauses were resolved to produce the new clause. I.e., "comment" your proof.)

- d) Briefly explain what it means for a theorem prover to be *complete*.

PROBLEM 5 - Forward-Chaining Production Systems (15 points)

- a) Consider the following production system that moves toy blocks around. Initially blocks A and B are on a table. Block C is on top of block A and block D is on top of block B. The goal is to rearrange the blocks so that block A is (directly) on block B.

*Production Rules**RULE 1*

if (SUBGOAL ?s) (GOAL (On ?x ?y)) (On ?x ?y)
 then (RETRACT (SUBGOAL ?s))

RULE 2

if (SUBGOAL ?s) (GOAL (On ?x ?y)) (ClearTop ?x) (ClearTop ?y)
 then (RETRACT (ClearTop ?y)) (ASSERT (On ?x ?y))

RULE 3

if (SUBGOAL none) (GOAL (On ?x ?y)) (On ?z ?x)
 then (RETRACT (SUBGOAL none)) (ASSERT (SUBGOAL (Move ?z)))

RULE 4

if (SUBGOAL none) (GOAL (On ?x ?y)) (On ?z ?y) (\neq ?x ?z)
 then (RETRACT (SUBGOAL ?s)) (ASSERT (SUBGOAL (Move ?z)))

RULE 5

if (SUBGOAL (Move ?x)) (On ?y ?x)
 then (RETRACT (SUBGOAL (Move ?x))) (ASSERT (SUBGOAL (Move ?y)))

RULE 6

if (SUBGOAL (Move ?x)) (On ?x ?y) (ClearTop ?x) (ClearTop ?z)
 (\neq ?x ?z) (GOAL (On ?m ?n)) (\neq ?z ?m) (\neq ?z ?n)
 then (RETRACT (SUBGOAL (Move ?x))) (RETRACT (On ?x ?y)) (RETRACT (ClearTop ?z))
 (ASSERT (ClearTop ?y)) (ASSERT (On ?x ?z)) (ASSERT (SUBGOAL none))

Initial Database

(On C A)	(On D B)	(ClearTop C)	(ClearTop D)	
(\neq A B)	(\neq A C)	(\neq A D)	(\neq B A)	(\neq B C)
(\neq C A)	(\neq C B)	(\neq C D)	(\neq D A)	(\neq D B)
(\neq B D)	(\neq D C)	(SUBGOAL none) (GOAL (On A B))		

Conflict-Resolution Mechanism

The lowest-numbered rule that matches is chosen. (Note: a rule may fire repeatedly with the same variable bindings.)

In the space below, list the order of rule firings; state the rule number and the variable bindings. Stop after five firings or when no rule is applicable.

1) _____ 2) _____ 3) _____ 4) _____ 5) _____

(over)

- b) Assume you were only allowed to RETRACT "control knowledge" - goals and subgoals. I.e., you could only assert additional facts about the blocks, but never delete existing ones. Briefly describe the major problem this would cause for writing productions rules for the "blocks world."

PROBLEM 6 - Certainty Factors (10 points)

Assume you are provided the following certainty-factor (CF) rules:

Rule 1: IF one's team is losing
 THEN one shouts
 CERTAINTY FACTOR = -0.8

Rule 2: IF one is at crowded place
 THEN one shouts
 CERTAINTY FACTOR = 0.6

- a) Assume you are in a crowded bar watching your team lose. With what certainty can one conclude that you are shouting?
- b) Assume you believe, with $CF=0.9$, that Wilma is in a crowded restaurant. According to the certainty-factor method, with what CF do you believe she is shouting?
- c) Assume you believe, with $CF=0.8$, that John shouts and you believe, with $CF=0.6$, that Mary shouts. With what CF do you believe *John shouts or Mary shouts*?

PROBLEM 7 - Backward Chaining and Prolog (15 points)

a) Consider the following Prolog rulebase.

```
p(a).  
p(b).  
r(1).  
r(2).  
m(a,b).  
n(2,1).  
n(b,a).  
f(b,b).  
f(1,1).  
m(X,Y) :- p(Y), r(X).  
g(X,Y) :- m(X,Z), n(W,Y), f(Z,Y).  
g(X,a) :- p(X), r(X).  
g(X,X) :- f(X,X), r(X).
```

For each of the following requests, determine how many ways Prolog can deduce an answer to the query. Hint: none of the answers are above 10. (If you wish to get partial credit for incorrect answers, also show the bindings of each proof for the variables in the query. Use the back of page 7 if necessary.)

i) ?- n(1,2). Number of Proofs: _____

ii) ?- m(C,D). Number of Proofs: _____

iii) ?- g(E,F). Number of Proofs: _____

b) Write a Prolog program for *same-family*(X,Y), which determines if X and Y have a common ancestor. You may only assume that the predicate *parent* is defined.

PROBLEM 8 - Problem-Reduction Search (5 points)

John is an AI student who has the goal of learning Lisp. Give an problem-reduction (i.e., AND/OR) tree showing how to accomplish this goal. Be sure to include at least *two* AND nodes and at least *two* OR nodes.