(PRINT) Name _____Student No_____

Signature _____Total Mark_____/100

The University of Toronto

Computer Science 384 – Introduction to Artificial Intelligence

Midterm Test 1
2003 February 7

Time: 45 minutes
Total marks: 100

Answer all questions on this paper. No books or other materials may be used. Calculators and personal computers are not permitted.

This examination has 6 pages. Check that you have a complete paper.

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1) [12 pts] Answer each part of the question in the space below.

a) Give a most general unifier for:

`p(g(f(X,Y)), f(Y,X), X)` and `p(g(U), f(a,V), g(W))`

[-1] for every substitution not in normal form

Answer: **{ X/g(W) [1], V/g(W) [2], Y/a [1], U/f(g(W), a) [2] }**

b) Give a unifier for the same expressions in item (a) that is NOT most general.

Answer: **{ X/g(a) [1], V/g(a) [1], Y/a [1], U/f(g(a), a) [2], W/a [1] }**

2) Consider a language with two unary predicate symbols, `p` and `r`, one binary predicate symbol `q`, one unary function symbol `f`, and two constants, `a` and `b`. The following KB has been specified in this language:

1. `p(a).`
2. `q(a,b).`
3. `q(a,f(b)).`
4. `q(a,f(f(b))) ← p(a) ∧ q(f(a),b).`
5. `q(f(X),Y) ← q(X,f(Y)).`
6. `r(Y) ← p(X) ∧ q(X,Y).`

a) [14 pts] Give all logical consequences of this KB.

[-1] for each missing:
p(a)
q(a, b)
q(a, f(b))

[-2] for each missing:
q(f(a), b)
q(a, f(f(b)))
q(f(a), f(b))
q(f(f(a)), b)

r(b)
r(f(b))
r(f(f(b)))

[-1] for extras

b) [8 pts] How many interpretations exist for this language with D = {α,β}? If the number is too large to compute by hand, it is sufficient to give an arithmetic expression.

ϕ mappings:
- **constants:** $2^2 = 4$ **[2]**
- **function:** $2^2 = 4$ **[2]**

π mappings:
- **unary p:** $2^2 = 4$ **[1]**
- **unary r:** $2^2 = 4$ **[1]**
- **binary q:** $2^4 = 16$ **[2]**

[-1] if total absent or wrong:
Total: 4 x 4 x 4 x 4 x 16 = 2^{12} = 4096

c) [8 pts] Are the following interpretations models of the knowledge base? Explain briefly why.

i)

$\phi(a)=\alpha$	$\pi(p,\alpha)=T$	$\pi(q,\alpha,\alpha)=T$
$\phi(b)=\beta$	$\pi(p,\beta)=F$	$\pi(q,\alpha,\beta)=T$
$\phi(f,\alpha)=\beta$	$\pi(r,\alpha)=T$	$\pi(q,\beta,\alpha)=T$
$\phi(f,\beta)=\alpha$	$\pi(r,\beta)=T$	$\pi(q,\beta,\beta)=T$

All facts are true except $\pi(p,\beta)=F$ which is not constrained to be true by the KB. [2]

Answer: **Yes [2]**

ii)

$\phi(a)=\alpha$	$\pi(p,\alpha)=T$	$\pi(q,\alpha,\alpha)=T$
$\phi(b)=\beta$	$\pi(p,\beta)=F$	$\pi(q,\alpha,\beta)=T$
$\phi(f,\alpha)=\beta$	$\pi(r,\alpha)=T$	$\pi(q,\beta,\alpha)=T$
$\phi(f,\beta)=\alpha$	$\pi(r,\beta)=F$	$\pi(q,\beta,\beta)=T$

[3] for either:

$\pi(r, \phi(b))$	**or**	**$\pi(r, \phi(f, \phi(f, \phi(b))))$**
$= \pi(r, \beta)$		**$= \pi(r, \phi(f, \phi(f, \beta)))$**
= false		**$= \pi(r, \phi(f, \alpha)))$**
		= false

Answer: **No [1]**

3) [12 pts] Consider the language that contains the constant symbols `sue`, `mary`, `peter`, `paul` and `carol`; the predicate symbols `mother`, `father`, `parent`, `grandmother`, `grandfather` and `grandparent`.

The following knowledge base is built from this language:

```
mother(sue, carol).
mother(mary, peter).
father(paul, peter).
father(peter, carol).
parent(X, Y) ← father(X, Y).
parent(X, Y) ← mother(X, Y).
grandfather(X, Y) ← father(X, Z) ∧ parent(Z, Y).
grandmother(X, Y) ← mother(X, Z) ∧ parent(Z, Y).
grandparent(X, Y) ← grandfather(X, Y).
grandparent(X, Y) ← grandmother(X, Y).
```

Give all answers for the query:

```
?grandparent(X, carol)
```

Answer:

mary [6]
paul [6]
extras [-4]

1 right [6]
1 complete derivation [10]
Only answer [8]
1 incomplete derivation [2]

4) [24 pts] The following clauses represent the neighbors in a search tree.

```
nb(a, [arc(d,2)]).
nb(b, [arc(a,2), arc(c,1)]).
nb(c, [arc(e,1)]).
nb(d, [arc(b,1), arc(f,2)]).
nb(e, [arc(d,1)]).
nb(f, [arc(d,1), arc(g,3)]).
nb(g, [arc(e,1)]).
```

Here the predicate `nb(X, ArcList)` is true iff `ArcList` is the list of directed arcs from node `X` to its neighbors. Each `arc(Node,Cost)` consists of a neighbor node and the cost of reaching it.

Given start state **b** and goal state **g**, for each of the search methods below, state the solution path returned by that method, if any, and the path cost. Assume that the neighbors of expanded nodes are added to the frontier in the order of the lists presented in the clauses unless criteria such as cost require otherwise. If a criterion such as cost is used and two nodes on the frontier have equal cost, assume that the first node placed on the frontier is the first one removed if such a tie exists.

Tip: you may want to draw a search tree to help yourself.

a) Depth-first search without cycle checking

Answer: **No path (trapped in cycle) [6]**

b) Depth-first search with cycle checking

Answer: **b – a – d – f – g [5] / Cost: 9 [1]**

c) breadth-first search with multiple path checking

Answer: **b – a – d – f – g [5] / Cost: 9 [1]**

d) Least-cost first search (no multiple path checking)

Answer: **b – c – e – d – f – g [5] / Cost: 8 [1]**

5) Answer the following questions (give SHORT answers):

a) [12 pts] Why doesn't it make sense to do multiple-path checking in DFS?

- **DFS with MPC requires storage of all visited nodes. [4]**
- **Space requirement becomes exponential (as opposed to linear). [4]**
- **BFS also takes exponential space but always returns optimal path. We may want as well do BFS. [4]**

b) [10 pts] You are given a language L and a knowledge base KB.

i) If we add more predicate symbols to the language L, does the number of interpretations decrease, stays the same or increase? Justify briefly.

Answer: increase [2]
Justification: The number of π mappings increases [3]

ii) If we add more clauses to the knowledge base KB, does the number of models decrease, stays the same or increase? Justify briefly.

Answer: decrease [1] or stays the same [1]
Justification: The KB imposes more constraints on π mappings [3]