Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Symbolic AI

Date: Tuesday 1st June 2010

Time: 09.45 – 11.45

Please answer any THREE Questions from the FOUR Questions provided

The use of electronic calculators is NOT permitted.
1. **Prolog and logic**
   
a) Briefly explain what is meant by “negation as failure” in Prolog. (2 marks)

b) What values are returned by the following calls to Prolog?

   i)  ?- not(not(a = X)), b = X.

   ii) ?- b = X, not(not(a = X)). (2 marks)

c) Using the Prolog predicates `call/1`, `!/0` (cut) and `fail/0`, define the predicate `my_not/1` in Prolog, so that it exhibits the normal (pre-defined) behaviour of `not/1`. (4 marks)

d) Using `!/0` (cut), but without using `not/1` (or `my_not/1`), write a Prolog predicate `rem_dup/2`, which removes duplicates from a list as follows:

   ?- rem_dup([1,2,1,3,1,2,3,2],L).
   L = [1,3,2]

   The predicate should not return incorrect answers on resatisfying. (You need not worry about the order of elements in the returned list.) (6 marks)

e) Write Prolog clauses corresponding to the formula

   \[ \forall x (\exists y (r(x,y) \lor r(y,x)) \rightarrow r(x,x)). \] (4 marks)

f) Explain briefly why the formula

   \[ \forall x \forall y \forall z ((r(x,y) \land r(x,z)) \rightarrow (r(y,z) \lor r(z,y))) \]

   cannot be expressed using Prolog clauses. (2 marks)
2. **Logic and theorem-proving**

a) Explain, in the context of first-order logic, what is meant by *prenex form.*
   (2 marks)

b) Translate the following sentence into a formula of first-order logic in prenex form, over the obvious signature of unary and binary predicates.

   Every carpenter admires some electrician.

   (You may find it helpful to write the formula down in the most natural way first, and then convert to prenex form afterwards.)
   (4 marks)

c) Explain, in the context of first-order logic, what is meant by *Skolemization.* What is the relationship between a formula and the result of Skolemizing it?
   (6 marks)

d) Skolemize the formula obtained in your answer to 2b.
   (2 marks)

e) In the lectures and laboratory exercises, we used the theorem-prover SATCHMO. Using your answer to 2d, write clauses in SATCHMO syntax corresponding to the premises

   No artist admires any dentist
   No beekeeper admires any non-dentist
   Every carpenter admires some electrician,
   (4 marks)

f) These premises entail that no artist is also both a beekeeper and a carpenter. What additional clauses do you have to add before calling the main SATCHMO goal, `satisfiable_level/0`, in order to prove this entailment?
   (2 marks)
3. **Prolog and natural language syntax**

   a) In the context of Prolog DCGs (definite clause grammars), explain how braces ({}) and square brackets ([]) are interpreted on the right-hand sides of rules. (2 marks)

   b) Write a Prolog predicate `stripInfl(V,VInfl)`, which, when called with `VInfl` instantiated to an atom ending in `s`, will instantiate `V` to the same atom with the final `s` removed, thus:

   ```prolog
   %- stripInfl(V,loves).
   V = love.
   ```

   (2 marks)

   c) Using the version of transformational grammar presented in the lectures, draw the phrase-structures of the IP (inflection phrase)

   Every boy loves some girl

   showing clearly the movement of the verb to join with the inflection. (4 marks)

   d) Write a definite clause grammar in Prolog to generate the phrase-structure (before movement) given in your answer to 3c, assuming a lexicon in the form of a set of Prolog facts

   ```prolog
   isNoun(boy).    isNoun(girl).    isVerb(love).
   isDet(some).    isDet(every).
   ```

   Your grammar need not compute the meaning of the sentence, but it should use variable-passing techniques to handle the verb-movement. (12 marks)
4. **Prolog, natural language semantics, and logic**

Consider the following semantically annotated context-free grammar:

\[
\begin{align*}
S/\phi(\psi) & \to NP/\phi, VP/\psi \\
VP/\phi(\psi) & \to \text{IdentityPhrase}/\phi, NP/\psi \\
\text{IdentityPhrase}/\lambda s \lambda x [s(\lambda y [x = y])] & \to \text{is identical to} \\
NP/\phi(\psi) & \to \text{Det}/\phi, N/\psi \\
\text{Det}/\lambda p \lambda q [\forall x (p(x) \to q(x))] & \to \text{every.}
\end{align*}
\]

a) Add grammar rules for the determiner “some” and the nouns “artist” and “beekeeper”. Use unary predicates artst (for artist), and bkpr (for beekeeper). (4 marks)

b) Compute the meaning of the sentences

Every artist is identical to some beekeeper

showing your working. (10 marks)

c) What meaning will be assigned to the following sentence?

Every artist is identical to every beekeeper (2 marks)

d) It is possible to write the formula in the answer to 4b, in a logically equivalent form, without using the equality predicate. Do so. (2 marks)

e) The conjunction of the pair of sentences

Every artist is identical to every beekeeper

No artist is a beekeeper

can be equivalently expressed as the disjunction of two formulas, one involving only the unary predicate artst, the other only the unary predicate bkpr. Find these two formulas. (2 marks)

END OF EXAMINATION