Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Artificial Intelligence Programming

Date – Wednesday 28th May 2008
Time – 09:45 – 11:45

Please answer any THREE Questions from the FOUR Questions provided.

The use of electronic calculators is NOT permitted.
1. a) Using an $\mathbf{X}$-style of analysis, draw trees representing the deep-structure of the sentences (IPs):

i) John will kiss Mary
ii) John kissed Mary

and explain how, in the latter case, the verb kiss moves to join with the past-tense inflection to produce the observed word order. (6 marks)

b) Write a CFG to generate the structures drawn in answer to part a). Your grammar may include the terminal productions

\[
\text{NP} \rightarrow \text{John} \\
\text{NP} \rightarrow \text{Mary} \\
\text{V} \rightarrow \text{kiss} \\
\text{I} \rightarrow \text{will} \\
\text{I} \rightarrow \_\text{ed}.
\]

(2 marks)

c) Suppose now we wish to semantically annotate the CFG given in answer to part b). In particular, we will employ annotated productions

\[
\text{NP}/\lambda p[p(\text{John})] \rightarrow \text{John} \\
\text{V}/\lambda x\lambda y[s(\lambda y [\text{kiss}(x,y,t)])] \rightarrow \text{kiss} \\
\text{I}/\lambda z\lambda x[\exists t (t < \text{now} \land z(t)(x))] \rightarrow \_\text{ed}.
\]

(Here kiss(x,y,t) is read: “x kisses y at time t”.)

Write out the rest of the semantically annotated grammar, and use it to derive the meaning assignment:

John will kiss Mary

\[
\exists t (t > \text{now} \land \text{kiss}(\text{john},\text{mary},t)).
\]

(12 marks)
2.  a) Write down first-order formulas (over the obvious signature) expressing the meanings of

\[ S_1: \] Every artist admires every artist
\[ S_2: \] No bookkeeper admires any bookkeeper
\[ S_3: \] Some artist is a genius
\[ S_4: \] Some artist is not a bookkeeper

(2 marks)

b) The CFG

\[
S \rightarrow NP \ VP \\
NP \rightarrow \ Det \ N \\
VP \rightarrow V \ NP \\
N \rightarrow \ artist \\
V \rightarrow \ admires
\]

recognises sentence \( S_1 \) in a). Add semantic annotations to yield the truth conditions you gave (up to logical equivalence), and show the derivation of the meaning of \( S_1 \).

(8 marks)

c) Define (or draw) a structure showing that \( S_1 \) and \( S_2 \) together do not entail \( S_4 \).

(2 marks)

d) Give a resolution proof showing that \( S_1, S_2 \) and \( S_3 \) together entail \( S_4 \).

(8 marks)
3. a) Explain how a Prolog fact

\[ a(s_1, \ldots, s_m) \]

and a Prolog rule

\[ a(s_1, \ldots, s_m) :- b_1(t_{1,1}, \ldots, t_{1,m_1}), \ldots, b_n(t_{n,1}, \ldots, t_{n,m_n}). \]

where \( a, b_1, \ldots, b_n \) are predicates and

\[ s_1, \ldots, s_m, t_{1,1}, \ldots, t_{1,m_1}, \ldots, t_{n,1}, \ldots, t_{n,m_n} \]

are terms, can be translated into sentences of first-order logic (over a suitable signature). (6 marks)

b) Write a Prolog program to reverse a list using accumulators. (4 marks)

c) Define the first order sentences \( \varphi_1, \varphi_2, \) and \( \varphi_3 \) as follows:

\[ \varphi_1 := \forall x \forall y \forall z \forall u (\text{rev}(y,d(x,z),u) \rightarrow \text{rev}(d(x,y),z,u)) \]

\[ \varphi_2 := \forall z \text{rev}(\text{nil},z,z) \]

\[ \varphi_3 := \text{rev}(d(1,d(2, \text{nil})), \text{nil}, d(2,d(1, \text{nil}))). \]

Show, using resolution theorem proving, that

\[ \varphi_1, \varphi_2 \vdash \varphi_3. \] (10 marks)
4. a) Explain the term ‘lexical ambiguity’ and give an example of an English sentence exhibiting lexical ambiguity. (3 marks)

b) Give the two first-order translations of the scope-ambiguous sentence

   Every boy loves some girl. (2 marks)

c) The following English sentences are all difficult to translate faithfully into first-order logic. In each case, identify the source of the difficulty and explain why it is a difficulty

   i) Dusty is a small animal, but a large hamster
   ii) There are infinitely many prime numbers
   iii) Mary owns a fake diamond
   iv) Gunner killed Ridley quickly. (8 marks)

d) Suppose it is suggested to translate

   Mary is a friend of Bill
   Jack is an enemy of Jill

   into first-order logic as

   friend (mary) \land of (mary, bill)
   enemy (jack) \land of (jack, jill).

   Give an argument to show that this is a poor translation. Give the correct translation. (7 marks)