Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Symbolic Artificial Intelligence [MOCK EXAM QUESTIONS]

X

Time: 2 hours

This is a HYBRID exam, with sections to be answered online and questions to be answered on paper.

Answer ALL questions.

Use a SEPARATE answerbook for each paper SECTION.

For full marks your answers should be concise as well as accurate.

Marks will be awarded for reasoning and method as well as being correct.

The use of electronic calculators is permitted provided they are not programmable and do not store text.

Section A

Answer ALL questions. These questions should be answered ON PAPER

1. **[Modelling and Representation]**

For this question you should select **one** of the representation formalisms covered in the course e.g. either Datalog, Prolog, or First-Order logic.

You have graduated and got your first job as a Computer Wizard at London Zoo. Your first job is to create an intelligent system for

a) You have a brief chat with the *Director of the Zoo* and he scribbles down some examples of facts you need to store in your system as follows:

- There are distinct categories of animals such as Amphibian, Arachnid, Bird, Fish, Insect, Mammal, and Reptile
- Every environment has a maximum capacity and a type of climate
- Both Amphibians and Fish need to live in marine environments
- Tigers are large animals, carnivores, and mammals
- Iguanas are small animals, herbivores, and reptiles
- Bhanu is a Lion of the Asiatic species and is kept in environment B12
- Environment A4 is accessible from environment A2

Describe a set of predicates that you would use to capture these facts and then use them to represent the facts in your chosen formalism. (3 marks)

b) You visit Susan, the *Head of Stopping Animals from Eating Each Other*, and she says that she wants to check that carnivores are only in environments accessible from other environments containing the same species of animal. Use your formalism to design some rules and a single query to allow Susan to check this. (3 marks)

c) Finally, some of the old Computer Wizards have been assigned to your project. They are familiar with the old system that used a relational database. Write a brief summary of how your chosen representation formalism relates to relational databases. You may find it helpful to refer to tables that might have existed in the old database and how they would relate to relations defined in your formalism. (3 marks)

2. **[Reasoning]** Use the resolution and superposition calculus (the rules are given at the end of the paper) to give a proof that this set of formulas

$$\begin{array}{l}
\forall x.(is_in(x,fruit_salad) \rightarrow fruit(x)) \\
\forall x.(is_in(x,potato_salad) \rightarrow (potato(x) \vee onion(x))) \\
\forall x.(potato(x) \rightarrow vegetable(x)) \\
\forall x.(onion(x) \rightarrow vegetable(x)) \\
\forall x.\neg(fruit \leftrightarrow vegetable(x))
\end{array}$$

entails

$$\neg\exists x.(is\_in(x, fruit\_salad) \wedge is\_in(x, potato\_salad)$$

You do not need to use the given clause algorithm (although may do so). Recall that you will first need to transform your problem into clausal form (the rules are given at the end of the paper). (6 marks)

Section B

Answer ALL questions. These questions should be answered ON PAPER

This is a second set of paper questions. In the actual exam there will only be one set of paper questions. The other 15 marks will be online and follow the style of the quizzes.

3. **[Modelling and Representation]**

   a) Write a set of Prolog rules to define the following predicates

   - `musician(X)` should be true if person `X` plays an instrument or sings
   - `band(X)` should be true if `X` is a list of musicians
   - `bad_band(X)` should be true if `X` is a band without a drummer (somebody who plays the drums)

   (3 marks)

   b) Briefly discuss advantages and disadvantages of using Prolog for this task rather than Datalog or first-order logic (2 marks)

4. **[Reasoning]**

   a) Translate each of the following statements in first-order logic into English

   i. $\forall x.\neg(cat(x) \leftrightarrow dog(x))$
   ii. $cat(garfield) \wedge dog(odie)$
   iii. $likes(garfield, lasagne)$
   iv. $\forall x, y, z.((cat(x) \wedge dog(y) \wedge likes(x,z)) \rightarrow \ likes(y,z))$

   (2 marks)

   b) Transform the above formulas into clausal form. The clausification rules are given at the end of this section. (2 marks)

   c) Apply the *given clause* algorithm with the rules (ordered) resolution, paramodulation, and equality resolution to show that the above set of formulas entails the formula

   $$\neg likes(odie, lasagne)$$

   These rules are given at the end of this section. You may select your own clause ordering and literal ordering. (6 marks)

Clausifcation Rules for First-Order Logic

Negation Normal Form

$$
\begin{array}{rcl}
\neg(F_1 \wedge \ldots \wedge F_n) & \Rightarrow & \neg F_1 \vee \ldots \vee \neg F_n \\
\neg(F_1 \vee \ldots \vee F_n) & \Rightarrow & \neg F_1 \wedge \ldots \wedge \neg F_n \\
F_1 \rightarrow F_2 & \Rightarrow & \neg F_1 \vee F_2 \\
\neg\neg F & \Rightarrow & F \\
\neg\forall x_1,\ldots,x_n F & \Rightarrow & \exists x_1,\ldots,x_n \neg F \\
\neg\exists x_1,\ldots,x_n F & \Rightarrow & \forall x_1,\ldots,x_n \neg F \\
\neg(F_1 \leftrightarrow F_2) & \Rightarrow & F_1 \otimes F_2 \\
\neg(F_1 \otimes F_2) & \Rightarrow & F_1 \leftrightarrow F_2 \\
F_1 \leftrightarrow F_2 & \Rightarrow & (F_1 \rightarrow F_2) \wedge (F_2 \rightarrow F_1); \\
F_1 \otimes F_2 & \Rightarrow & (F_1 \vee F_2) \wedge (\neg F_1 \vee \neg F_2).
\end{array}
$$

Skolemization

$$
\begin{array}{rcl}
\forall x_1,\ldots,x_n F & \Rightarrow & F \\
\exists x_1,\ldots,x_n F & \Rightarrow & F\{x_1 \mapsto f_1(y_1,\ldots,y_m),\ldots,x_n \mapsto f_n(y_1,\ldots,y_m)\},
\end{array}
$$

Clausal Normal Form

$$
\begin{array}{rcll}
(A_1 \wedge \ldots \wedge A_m) \vee B_1 \vee \ldots \vee B_n & \Rightarrow & (A_1 \vee B_1 \vee \ldots \vee B_n) & \wedge \\
& & \cdots & \wedge \\
& & (A_m \vee B_1 \vee \ldots \vee B_n). &
\end{array}
$$

Reasoning Rules for First-Order Logic

Ordered Resolution

$$
\frac{l_1 \vee C \qquad \neg l_2 \vee D}{(C \vee D)\theta} \quad \theta = \mathsf{mgu}(l_1, l_2)
$$

where l_1 and $\neg l_2$ are selected by a well-behaved selection function.

Paramodulation and Equality Resolution

$$
\frac{C \vee s = t \qquad l[u] \vee D}{(l[t] \vee C \vee D)\theta} \quad \theta = \mathsf{mgu}(s, u) \qquad\qquad \frac{s \neq t \vee C}{C\theta} \quad \theta = \mathsf{mgu}(s, t)
$$

END OF EXAMINATION