

The University of Nottingham

SCHOOL OF COMPUTER SCIENCE

A LEVEL 3 MODULE, AUTUMN SEMESTER 2016-2017

KNOWLEDGE REPRESENTATION AND REASONING

Time allowed TWO hours

Candidates may complete the front cover of their answer book and sign their desk card but must NOT write anything else until the start of the examination period is announced

Answer all FOUR questions

Only silent, self contained calculators with a Single-Line Display are permitted in this examination.

Dictionaries are not allowed with one exception. Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination. Subject specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries, may be used.

DO NOT turn your examination paper over until instructed to do so

1. This question is on expressing knowledge in first-order logic and logical entailment.
 - (a) Translate the sentences below from English into first-order logic. Use predicate symbols *Region* for spatial regions, *Disjoint* (where $Disjoint(x, y)$ means that x and y are disjoint), *Included* (where $Included(x, y)$ means that x is included in y), *Overlap* (where $Overlap(x, y)$ means that x and y overlap) and constants *dorset*, *fife*, *scotland*, *england*.
 - i. Any two regions are either disjoint, overlapping, or one of them is included in another. (2 marks)
 - ii. Every region is included in itself. (1 marks)
 - iii. If two regions are disjoint, they are not overlapping. (1 marks)
 - iv. If two regions are overlapping, none of them is included in another. (2 marks)
 - v. If one region is included in another, then they are not disjoint. (1 marks)
 - vi. If two regions are disjoint, then any region included in the first one is disjoint from the second one. (2 marks)
 - vii. Dorset and England are regions, Dorset is included in England. (1 marks)
 - viii. Fife and Scotland are regions, Fife is included in Scotland. (1 marks)
 - ix. Scotland and England are disjoint. (1 marks)
 - (b) Do the sentences from part (a) logically entail that Dorset does not overlap with Scotland? Justify your answer by giving a definition of logical entailment. Either show that entailment holds by reasoning about all possible interpretations (NOT by using resolution), or show that it does not hold by giving a counterexample interpretation. (7 marks)
 - (c) Do the sentences from part (a) logically entail that Fife does not overlap with Dorset? Either show that entailment holds by reasoning about all possible interpretations (NOT by using resolution), or show that it does not hold by giving a counterexample interpretation. (6 marks)

2. This question is on clausal form, resolution and unification.

(a) Reduce the following sentences to clausal form: (10 marks)

S1 $\forall x \forall y (\neg(R(x, y) \wedge \neg R(y, x)))$

S2 $\exists z \forall x \exists y P(x, y, z)$

S3 $\forall x \forall y \exists z (\neg R(x, z) \vee \neg R(y, z))$

S4 $\neg \forall x \exists y (R(x, y) \vee R(y, x))$

S5 $\forall x \forall y \forall z (R(x, y) \supset (R(y, z) \supset R(x, z)))$

(b) Derive by resolution an empty clause from the following clauses (where x, y, z are variables and a and b constants): (10 marks)

C1 $[\neg R(x, x)]$

C2 $[\neg R(x, y), R(y, x)]$

C3 $[\neg R(x, y), \neg R(y, z), R(x, z)]$

C4 $[R(a, b)]$

(c) For the pairs of literals below, state whether they unify, and if yes give a most general unifier. Note that x, y, z, u are variables and a, b constants.

i. $P(x, x, y), \neg P(a, b, z)$ (1 marks)

ii. $R(x, f(x)), \neg R(y, z)$ (2 marks)

iii. $R(x, f(x)), \neg R(f(y), y)$ (2 marks)

3. This question is on backward and forward chaining.
- (a) Give the backward chaining procedure for propositional Horn clauses. (5 marks)
 - (b) Trace the backward chaining procedure on the following example:
 $KB = \{[\neg Elephant, Herbivore],$
 $[\neg Herbivore, \neg Large, EatsLots],$
 $[\neg Elephant, Large], [Elephant]\},$
goal: $EatsLots$. (5 marks)
 - (c) Give the forward chaining procedure for propositional Horn clauses. (5 marks)
 - (d) Trace the forward chaining procedure on the example from part (b)
(show that $EatsLots$ is derivable by forward chaining). (5 marks)
 - (e) Which of the two procedures is guaranteed to terminate and why? (5 marks)

4. This question is on non-monotonic reasoning.

(a) What is non-monotonic reasoning? Why is it used in knowledge-based systems? Give an example of how non-monotonic reasoning may be used in a knowledge-based system. (9 marks)

(b) Explain what a default rule $\frac{\alpha : \beta}{\delta}$ in Reiter's default logic means. (3 marks)

(c) What is an extension of a default theory (F, D) (where F is a set of first order sentences and D a set of default rules)? (5 marks)

(d) Is $P(c)$ a logical consequence of the following default theory (F, D) ? List all possible extensions of this theory and explain your working.

$$F = \{R(a), R(b), R(c), \neg(a = b), \neg(b = c), \neg(a = c), \neg P(a) \vee \neg P(b)\}$$

and

$$D = \left\{ \frac{R(x) : P(x)}{P(x)} \right\}$$

(8 marks)