

The University of Nottingham

SCHOOL OF COMPUTER SCIENCE

A LEVEL 3 MODULE, AUTUMN SEMESTER 2017-2018

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. (10 marks)
Use constants m for Colonel Mustard, p for Mrs Peacock, l for library, and t for 12 p.m. Please use predicates $Murderer^4$, In^3 , O^1 , M^1 , where $Murderer(x, y, z, u)$ stands for x murdered y at place z at time u , $In(x, y, z)$ stands for x was at place y at time z , $O(x)$ means x had an opportunity and $M(x)$ means that x had a motive.
- S1** Somebody murdered Colonel Mustard in the library at 12 p.m., and there is exactly one person who is the murderer of Colonel Mustard.
- S2** Anybody who was in the library at 12 p.m. had an opportunity to murder Colonel Mustard.
- S3** Mrs Peacock was in the library at 12 p.m.
- S4** More than one person had a motive to murder Colonel Mustard.
- S5** A person is a murderer of Colonel Mustard if only if they had a motive to murder Colonel Mustard and an opportunity to do so.
- (b) Give a definition of logical entailment. (5 marks)
- (c) Do the sentences from part (a) logically entail that Mrs Peacock murdered Colonel Mustard? Justify your answer referring to the definition of logical entailment. (10 marks)

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

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

$$\mathbf{S1} \quad \forall x \forall y \forall z (R(x, y) \wedge R(x, z) \supset \exists u (R(y, u) \wedge R(z, u)))$$

$$\mathbf{S2} \quad \forall x \forall y \forall z (R(x, y) \wedge R(y, z) \supset R(x, z))$$

$$\mathbf{S3} \quad \forall x R(x, x)$$

$$\mathbf{S4} \quad \forall x \forall y \forall z (R(x, y) \wedge R(x, z) \supset R(y, z))$$

$$\mathbf{S5} \quad \forall x \forall y (R(x, y) \supset R(y, x))$$

(b) Show by resolution that S1-S4 above logically entail S5. (10 marks)

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

i. $P(f(x), g(a), h(x, y))$ and $P(f(g(b)), g(z), u)$ (2 marks)

ii. $P(f(x), x, h(x, y))$ and $P(z, g(z), h(u, w))$ (2 marks)

iii. $P(f(a), g(a), h(x, y))$ and $P(f(g(b)), g(z), u)$ (1 marks)

3. This question is on Horn clauses, rule-based systems and propositional resolution.

- (a) Define Horn clauses and give examples of positive Horn clauses and negative Horn clauses. (5 marks)
- (b) What is conflict resolution in production rule systems? State the conflict set and give an example of a conflict resolution strategy for the production system below: (7 marks)

Rule 1 $\forall x(InDoubt(x) \supset Scream(x))$

Rule 2 $\forall x(InDoubt(x) \supset Shout(x))$

Fact 1 $InDoubt(tom)$

Fact 2 $InDoubt(jerry)$

- (c) Does forward chaining terminate if terms may contain function symbols? If yes, explain why, if not, give an example of a set of rules and facts for which forward chaining does not terminate. (5 marks)
- (d) This question is on propositional forward chaining. Given a set of n propositional rules of the form $p_1 \wedge \dots \wedge p_k \supset q$ and m propositional facts of the form p_i , how many new facts can be generated (at most)? (3 marks)
- (e) This question is on propositional resolution. Given a set of clauses which contain n different propositional symbols, is the search for the derivation of an empty clause by propositional resolution guaranteed to terminate, and if yes, after how many application of the resolution rule (at most)? (5 marks)

4. This question is on ontologies and description logic

- (a) What are ontologies? Give examples of widely used ontologies. (3 marks)
- (b) What is the relationship between W3C Web Ontology Language (OWL), OWL DL, and Description Logic? (5 marks)
- (c) State the definition of concept construction in description logic ALC. Hint: assume an alphabet of atomic concepts A_1, \dots, A_n, \dots and roles r_1, \dots, r_m, \dots (5 marks)
- (d) Translate the following definitions and inclusion statements into ALC, using atomic concepts *Vegetarian*, *Person*, *Meat*, *Fish*, *Animal*, *Vegan*, and roles *Eats* and *ProductOf*:
 - i. A vegetarian is a person who does not eat meat and does not eat fish (3 marks)
 - ii. A vegan is a person who does not eat animal products (3 marks)
 - iii. The concepts of non-vegetarian and vegan are disjoint (3 marks)
 - iv. Everyone who eats meat also eats animal products (3 marks)