UNIVERSITY OF DUBLIN
TRINITY COLLEGE

Faculty of Engineering, Mathematics and Science
School of Computer Science & Statistics

Integrated Computer Science
Year 4 Annual Examination

Artificial Intelligence IIa

Monday 05/01/2015 LUCE UPPER 9:30-11:30
Dr Tim Fernando

Instructions to Candidates:
Attempt two questions (out of the three).
Each of the three questions is scored out of a total of 50 marks.
You may not start this examination until you are instructed to do so by the Invigilator.

Materials permitted for this examination:
Non-programmable calculators are permitted for this examination — please indicate the make and model of your calculator on each answer book used.
1. (a) What does *non-determinism* have to do with artificial intelligence? [5 marks]

(b) Explain the sense in which deterministic finite automata and non-deterministic finite automata differ by an exponential. [10 marks]

(c) How do Turing machines differ from finite automata, and why is non-determinism in Turing machines more interesting from the perspective of AI than non-determinism in finite automata? [10 marks]

(d) How can the computation of a finite automaton be formulated as search? Why does depth-first search suffice for non-deterministic finite automata but not for non-deterministic Turing machines? [15 marks]

(e) What is the Satisfiability (SAT) problem and what does it have to do with non-determinism? [10 marks]
2. (a) How are actions analyzed in STRIPS? Illustrate your answer, using the move right action by a Turing machine. Are non-deterministic Turing machines a problem for STRIPS' analysis of action? Explain.

[10 marks]

(b) In what sense is STRIPS procedural and the situation calculus declarative?

[5 marks]

(c) What does the Büchi-Elgot-Trakhtenbrot theorem say about Monadic Second-Order Logic (MSO) and how is it relevant to actions analyzed under STRIPS and the situation calculus?

[5 marks]

(d) How is the string 1101 understood as a model of MSO over the alphabet \( \Sigma = \{0, 1, 2\} \)?

[5 marks]

(e) Give an MSO\(_{0,1}\)-sentence equivalent to the regular expression \((1 + 01)^+\). For full credit, keep your MSO\(_{0,1}\)-formula concise.

[10 marks]

(f) Recall that the inverse image of a regular language under a relation computed by a finite-state transducer is regular.

(i) How is this fact relevant to the Büchi-Elgot-Trakhtenbrot theorem?

[5 marks]

(ii) Let us agree to encode a finite-state transducer/automaton as a list \([Tr, Fi, Q0]\) consisting of a list \(Tr\) of transitions (triples in the case of an automaton, and quadruples in the case of a transducer), a list \(Fi\) of final states, and an initial state \(Q0\).

Write Prolog code for the 6-ary predicate

\[
\text{preImage}(+TrA, +FiA, +QA, +TrT, +FiT, +QT, +TrR, +FiR, +QR)
\]

so that \([TrR, FiR, QR]\) is a finite automaton accepting the inverse image of the language accepted by \([TrA, FiA, QA]\) under the relation computed by \([TrT, FiT, QT]\).

[10 marks]
3. (a) Translate the following sentence into Description Logic.

Every horse owned by a farmer has a black tail.

What bits of your analysis are taxonomic? What bits are mereological? Explain.

[15 marks]

(b) Specify the semantics in Description Logic for the concepts $(\exists R)C$ and $(\forall R)C$
    built from a role $R$ and a concept $C$.

[10 marks]

(c) Describe the sense in which the semantics of Description Logic is extensional,
    and runs counter to views in cognitive science about prototypes.

[5 marks]

(d) Consider the Description Logic sentence

$$(\exists R)A \cap (\exists R)B \subseteq (\exists R)(A \cap B)$$


[20 marks]