# UNIVERSITY OF OTAGO EXAMINATIONS 2012

## COMPUTER SCIENCE

### Paper COSC343

### ARTIFICIAL INTELLIGENCE

**(TIME ALLOWED: THREE HOURS)**

This examination consists of 7 pages including this cover page.

Candidates must answer **five questions in total**.

Questions are worth 12 marks and submarks are shown thus: (5)

No supplementary material is provided for this examination.

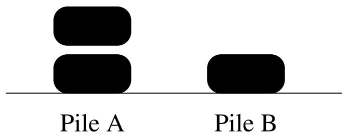
Candidates may not bring reference books, notes, or other written material into this examination room.

Use of calculators: No restriction on the model of calculator to be used, but no device with communication capability shall be accepted as a calculator. Calculators are subject to inspection by the examiners.

At the end of the examination, hand in this exam paper attached to your answer book(s).

1. **Adversarial search**

In the game of **Nim**, counters are placed in a number of piles, and the two players take it in turns to remove counters. A player can only remove counters from a single pile—but can remove as many counters as s/he wants from this pile. The winner of the game is the player who removes the last counter. A simple start state is shown below. There are two piles: pile A has two counters and pile B has one.




You are playing MAX, and your opponent is MIN. Assume MAX takes the first turn.

(a) Draw a tree representing the complete **state space** of the game. The root of the tree should represent the start state shown above. The tree should be organised into **plies** representing alternating turns of MAX and MIN. Clearly indicate the state of the game (i.e. what's in each pile) at each node of the graph, and label each arc with the move being made. (4)

(b) On the tree you produced for part (a), annotate each leaf node with the results of an **evaluation function** on game states, which assigns a win for MAX $+\infty$ and a loss for MAX $-\infty$. (2)

(c) Describe in detail how MAX would conduct a **minimax search** of the state space of the game, beginning from the start state. (It will help to add labels to the nodes in your tree, so you can refer to these in your description.) Your description should include an account of the backed-up values given to all non-leaf nodes. What move does minimax suggest MAX should make? (4)

(d) The state space for the simple version of Nim described here can be searched exhaustively, but if there are more piles and/or more counters, this can become impractical. Describe a version of minimax search which operates in spaces which are too big to search exhaustively. (2)

2. **Logic and Knowledge Representation**

A market researcher plans to build a knowledge base (KB) of information about students, stored in the predicate calculus. She conducts a survey, and records the following facts:

F1: All students own a mobile phone.
F2: All mobile phones include a SIM card.
F3: Henri is a student.

The researcher wants to use resolution refutation to pose queries to the KB. As a test, she plans to query the truth of the following fact:

F4: Henri owns a SIM card.

(a) Express the query sentence F4 in the predicate calculus. (Remember that object constants should be capitalised, and variables start with a lower-case letter.) The sentence should include an existential quantifier. (1)

(b) How should facts F1–F3 be expressed in the predicate calculus, in a way which supports an answer to the query? (You will need to use both existential and universal quantifiers.) (3)

(c) The researcher needs to add an **implicit premise** to the KB before posing the query. State this premise in natural language, and also in the predicate calculus. (2)

(d) In resolution refutation, the query sentence is negated and added to the KB. Express the negation of query sentence F4. (Remember that $\neg\exists x \phi \models \forall x \neg\phi$.) (1)

(e) Convert all sentences in the KB (including the implicit premise and negated query) to conjunctive normal form. (Remember that existentially quantified variables must be replaced by Skolem functions.) Show your working. (3)

(f) Use resolution refutation on the CNF sentences to prove that Henri does indeed own a SIM card. Show your working. (2)

3. **Natural language**

Consider the following sentence:

The man saw the girl with a telescope.

(a) This sentence is **semantically ambiguous**: it has two possible meanings. Express each of these meanings in an unambiguous natural language sentence. (2)

(b) The sentence is semantically ambiguous because it is **syntactically ambiguous**: it has two possible syntactic analyses.

(i) Write down a **context-free grammar** which permits both syntactic analyses of the sentence to be represented. As a starting point, you should include the following phrase-structure rules: (4)

| | |
|---|---|
| vp → vp, pp | pp → p, np |
| np → np, pp | p → with |

(ii) Draw the two possible syntactic analyses of the sentence which your grammar permits. (3)

(c) The phrase-structure rules on the left of the above table are **recursive**: in each case there is a phrase (vp or np) which appears both on the left of the rule and on the right. These rules allow your grammar to generate an *infinite* space of sentences. Explain how this is possible, using additional sentences generated by your grammar to illustrate. (3)

4. **Decision trees**

A decision tree is a tree-like structure that reaches a decision by performing a sequence of tests on its input attributes expressed as nodes. Thus, an internal node represents a test of the value of one of the input attributes, branches represent possible values of that test and each leaf node specifies an output value that represents a decision to be made.

- Task: Construct a decision tree for deciding whether to move forward (T or F) at the traffic intersection with the traffic lights without causing a traffic accident.

(a) Assume that the decision tree will include the following attributes: GreenLight (T or F), FrontOfQueue (T or F), PedestriansPresent (T or F). Using your common-sense knowledge about traffic light scenarios, define at least two more relevant attributes to include, specifying the possible values of each. (2)

(b) Using all attributes from part (a), create a table of at least 6 training examples like in the restaurant example in the lecture. (4)

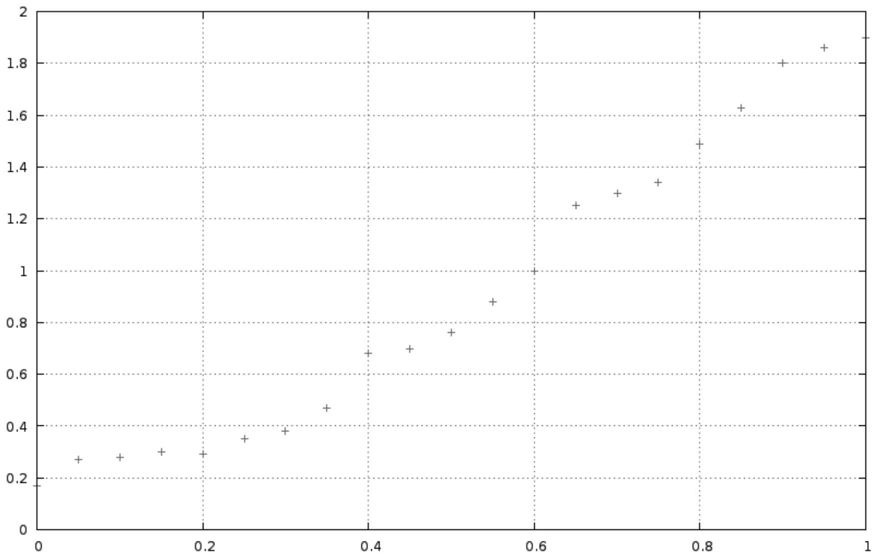
(c) Draw a minimal decision tree consistent with all the training examples from the table from part (b). (4)

(d) Will this decision tree always decide correctly whether to move forward at the intersection? Explain your answer in either case. (1)

(e) How can this decision tree be improved to yield more accurate decisions in new situations? (1)

5. **Machine learning and neural networks**

Describe how you would set up a multilayer perceptron (MLP) consisting of input, hidden and output layer to approximate the following function:




The cross marks denote the training samples. Answer the following questions:

(a) How many *input* units will you use in your MLP and why? (1)

(b) What numbers will constitute the input to MLP? (1)

(c) How many *output* units will you use in your MLP and why? (1)

(d) What numbers will be the desired (target) outputs? (1)

(e) What will be the activation function of the *output* unit(s)? (1)

(f) How many *hidden* units will you use in your MLP and why? (2)

(g) What will be the activation function of the *hidden* units? (1)

(h) Draw the architecture of MLP for this task. (1)

(i) How would you calculate an error signal for the *output* unit(s)? (1)

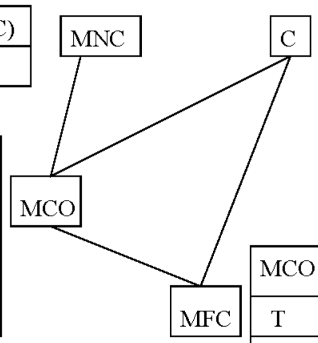
(j) The goal of training is to generalise to the points that are not part of the training set. How would you test the generalisation performance in this particular example? (2)

6. **Bayesian networks and probabilistic reasoning**

Consider the following Bayesian network, featuring the Boolean variables $C$ (cold weather), $MNC$ (Mary has a new coat), $MCO$ (Mary has a coat on) and $MFC$ (Mary feels cold):

| P(MNC) |
|---|
| 0.1 |

| P(C) |
|---|
| 0.4 |




| MNC | C | p(MCO\|MNC,C) |
|---|---|---|
| T | T | 0.9 |
| T | F | 0.4 |
| F | T | 0.6 |
| F | F | 0.1 |

| MCO | C | p(MFC\|MCO,C) |
|---|---|---|
| T | T | 0.4 |
| T | F | 0.0 |
| F | T | 0.9 |
| F | F | 0.2 |

(a) Fill in the missing columns in the conditional probability tables, i.e. columns for $P(\neg MNC)$, $P(\neg C)$, $P(\neg MCO|MNC, C)$ and $P(\neg MFC|MCO, C)$. (2)

(b) Calculate the probability that Mary has a new coat, and it is not cold, and Mary has a coat on, and Mary is not feeling cold. In other words, calculate the joint probability $P(mnc \land \neg c \land mco \land \neg mfc)$. Show your working. (3)

(c) How would you estimate this probability, i.e. $P(mnc \land \neg c \land mco \land \neg mfc)$ using the method of approximate inference by rejection sampling based on evidence? (3)

(d) Explain what it means to say that the Boolean variables $MCO$ (Mary has a coat on) and $BCO$ (Bill has a coat on) are not independent of one another, but are *conditionally* independent of one another given the variable $Rain$? (1)

(e) Assuming this conditional independence, what will the posterior probability $P(mco|rain \land bco)$ be equal to? (1)

(f) There are some salient things to be read from the conditional probability tables in the Bayesian network above. Thus, what kind of person is Mary judging from this network with given probabilities? (2)