UNIVERSITY OF OTAGO EXAMINATIONS 2011

COMPUTER SCIENCE

Paper COSC343

ARTIFICIAL INTELLIGENCE

Semester One

(TIME ALLOWED: THREE HOURS)

This examination consists of 8 pages including this cover page.

This examination consists of three sections, A, B and C. Candidates must answer **at least one question from each section**.

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

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

The total number of marks available for this examination is 60.

No supplementary material is provided for this examination.

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.

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

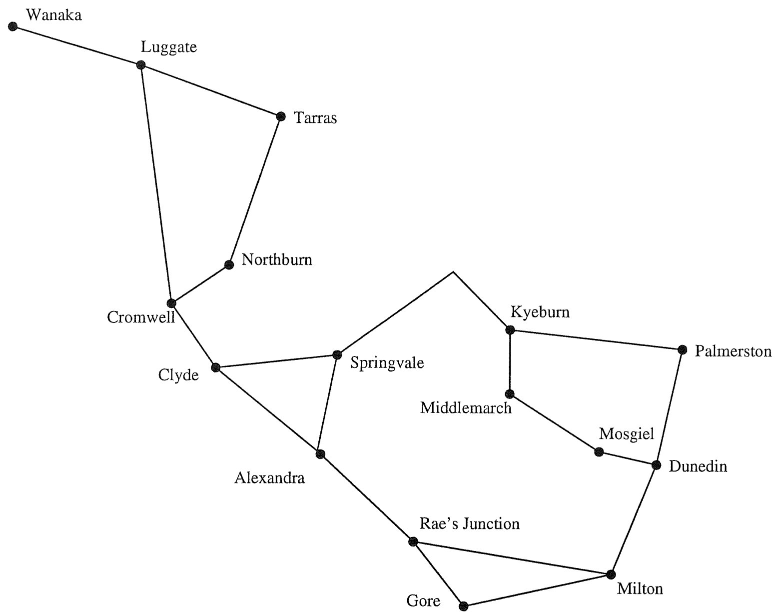
At the end of the exam please hand in the entire examination paper attached to your answer book.

TURN OVER

Section A

1. **Search**

A student wishes to travel from Dunedin to Wanaka. She plans her route by consulting the following crudely drawn map, together with a table listing points on the map in order of increasing straight-line distance from Wanaka.



Ranking table
Wanaka
Luggate
Tarras
Northburn
Cromwell
Clyde
Springvale
Alexandra
Kyeburn
Middlemarch
Rae's Junction
Gore
Palmerston
Mosgiel
Dunedin
Milton

(a) The map defines a **state space** comprising a set of nodes connected by arcs. What do the nodes and arcs in the state space represent in this case? (2)

(b) The student decides to use a **greedy search algorithm** to plan a route from Dunedin to Wanaka, using straight-line distance to Wanaka as a **heuristic** to evaluate nodes in the state space.

(i) Explain in general how a greedy search algorithm works. (3)

(ii) Draw the search tree which is created by a greedy search of the above state space, starting at Dunedin and ending at Wanaka. (3)

(c) Greedy search algorithms do not always find the optimal route to a goal state. Draw a simple map (including start and goal points) for which a greedy algorithm finds a suboptimal route to the goal. (2)

(d) Greedy search algorithms sometimes fail to find *any* route to a goal state. Draw another map (including start and goal points) for which a greedy algorithm fails to find any route to the goal, even though there is such a route. (2)

2. **Logic**

Here is a small knowledge base of sentences in the predicate calculus, stating some facts about a princess called Sally.[1]

S1.	$born\_a\_princess(Sally) \vee \exists a[prince(a) \wedge married(Sally, a)]$
S2.	$\neg born\_a\_princess(Sally)$

(a) Express S1 and S2 in natural language (assuming a common-sense interpretation of the predicates $born\_a\_princess$, $prince$ and $married$). (2)

(b) Express S1 in **clause form**. (You will need to use Skolemisation.) (2)

(c) S1 and S2 **entail** a further sentence S3, shown below:

$\boxed{\text{S3.} \quad \exists x[prince(x) \wedge married(Sally, x)]}$

(i) What does it mean, in general, to say that a knowledge base of sentences KB entails another sentence ψ? Make reference to the concept of **possible models** in your answer. (2)

(ii) Write down a predicate calculus sentence representing the *negation* of sentence S3, in a format which features a **universal quantifier**. (2)

(iii) Express the negation of sentence S3 in natural language. (1)

(iv) Show by **resolution refutation** that S1 and S2 entail S3, indicating any variable substitutions you make in the resolution process. (3)

[1] Recall that object constants are capitalised while variables are lower-case.

3. **Natural language**

The following table shows two groups of word sequences. Those on the left are well-formed English sentences, while those on the right are ill-formed English sentences.

Well-formed English sentences	Ill-formed English sentences
Dunedin is magnificent	*John think Dunedin is magnificent
Bill thinks I am magnificent	*John am magnificent
I think John thinks Dunedin is magnificent	*I thinks Dunedin is magnificent

(a) Write a **context-free grammar** which classifies the sequences on the left as well-formed, and those on the right as ill-formed. Your grammar should use variables to represent subject-verb agreement in person and number, and should contain a recursive rule. As a start, here are some of the lexical entries for your grammar:

pn(3, singular)	$\rightarrow$	Bill, John, Dunedin
pronoun(1, singular)	$\rightarrow$	I
be_verb(3, singular)	$\rightarrow$	is
be_verb(1, singular)	$\rightarrow$	am
adj	$\rightarrow$	magnificent

(8)

(b) Write down a word sequence which your grammar classifies as well-formed, but which you feel is an ill-formed or unusual English sentence. Discuss what the grammar seems to be getting wrong, and what could be done to fix the problem. (4)

Section B

4. **Decision trees**

A group of New Zealand entrepreneurs assemble a database to try and predict the movements of the Dow Jones financial index. The database is given below.

Iraqi_insurgents_lose	Libya_rebels_win	NATO_air_strikes	**Dow_Jones_Rises**
T	T	F	T
T	F	F	F
T	T	T	T
T	F	T	T
F	T	T	F
F	F	F	F

(a) The entrepreneurs want to build the simplest possible decision tree from their data. Use a pseudocode to describe the algorithm, which will construct such a tree. The algorithm should make reference to the amount of **information** carried by each variable in the tree. (5)

(b) Draw the maximally compact decision tree that can be induced from the data. (3)

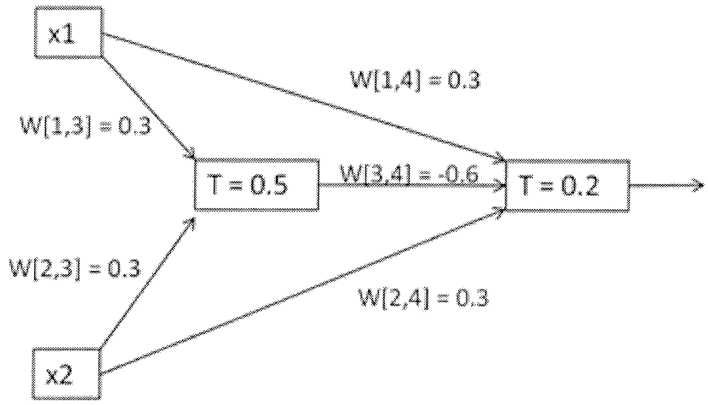
(c) The entrepreneurs construct a compact decision tree which works perfectly on their training data. However, when they test it the next day, it fails to predict the Dow Jones index's actual movement. Why might this be? What should the entrepreneurs do to improve their model? (4)

5. **Neural networks**

This question is about multi-layer perceptron (MLP).

(a) Show that a simple MLP with two binary units illustrated in this figure is able to calculate the XOR function. Explanation of the symbols in this figure: x1 and x2 are the inputs, letter T denotes the threshold of the binary perceptron and W[i, j] denotes the weight of the connection from unit i to unit j.

- The output of a binary unit j, out[j] = 1 if $\sum_i$ W[i, j] x[i] – T[j] $\geq$ 0, and out[j] = 0, otherwise. (4)



(b) Imagine we do not know the values of weights and thresholds of this MLP. How would you proceed to train this MLP to perform XOR? What would be you training set? Write a pseudocode for training your MLP. How would you test your MLP? When would you stop the training? (4)

(c) The MLP in the figure contains just binary units. What is the hypothesis space of this MLP? How the hypothesis space would change if the activation function of these two units was a sigmoid function? What would we gain if we included more than one nonlinear unit in the hidden layer? How many units do we need to have in the hidden layer? (4)

6. **Bayesian inference**

For a nuclear power station, consider these Boolean variables:

- A with values $\{A, \neg A\}$ = alarm sounds, alarm does not sound;
- F_A with values $\{F_A, \neg F_A\}$ = alarm is faulty, alarm is not faulty;
- F_G with values $\{F_G, \neg F_G\}$ = gauge is faulty, gauge is not faulty;
- G (gauge temperature reading) with values $\{G, \neg G\}$ = high, normal; and
- T (actual core temperature) with values $\{T, \neg T\}$ = high, normal.

(a) Draw a Bayesian network for this domain, given the domain knowledge that the temperature gauge reading depends on the actual core temperature and that the gauge is more likely to fail when the core temperature gets too high. The gauge reading itself is influenced by whether the gauge is faulty or not. An alarm sounds when the temperature gauge reading exceeds a given threshold in case it itself is not faulty. (3)

(b) Accompany each node of your Bayesian network with a corresponding conditional probability table (CPT). Fill them in with your estimates of probabilities. (4)

(c) Describe how you would determine the conditional probability $P(T|A, \neg F_G, \neg F_A)$, which is the probability that the temperature of the core is too high (T = high), providing the alarm is not faulty ($\neg F_A$) and the gauge is not faulty ($\neg F_G$) and the alarm sounds (A) by means of approximate inference by direct sampling and rejection sampling. What is the formula for estimating the conditional probability by rejection sampling? (5)

Section C

7. **Contrasting AI paradigms**

An AI system called HAL operates in the domain of medical diagnosis. The user inputs a list of symptoms for a given patient, and HAL returns a diagnosis for that patient.

(a) Assume HAL works using logical representations and a reasoning algorithm. Discuss, using some examples, how HAL might represent possible symptoms and diagnoses, and how it might arrive at a diagnosis given a list of symptoms. (4)

(b) Assume HAL works using EITHER probabilistic reasoning OR a neural network. Discuss, using some examples, how HAL might represent possible symptoms and diagnoses, and how it might arrive at a diagnosis given a list of symptoms. (4)

(c) Compare the two system architectures you have just described. What are the advantages and disadvantages of each? (4)