Student ID: ____________________

UNIVERSITY OF OTAGO EXAMINATIONS 2013

COMPUTER SCIENCE

Paper COSC343

ARTIFICIAL INTELLIGENCE

Semester 1

(TIME ALLOWED: THREE HOURS)

This examination consists of 7 pages including this cover page.

Candidates should answer questions as follows:

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

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

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.

Other Instructions

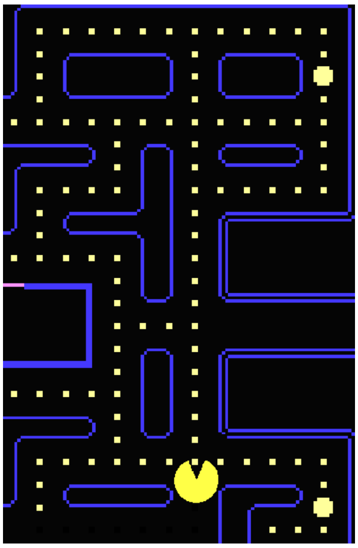
Please write your Student ID at the top of this page.

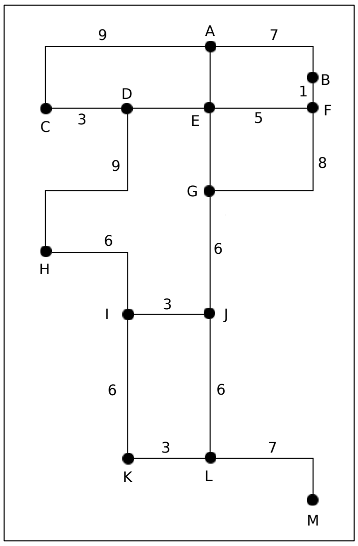
At the end of the examination, hand in this exam paper attached to your answer book(s).

TURN OVER

1. **Search**

You are developing a search algorithm for an AI system which plays the game Pacman. A portion of an example game is illustrated in the left-hand figure below. The AI agent is the  symbol. This agent must navigate a maze of paths (shown by the small yellow circles) and consume the power pills (shown by the large yellow circles). A state-space representation of the example maze is shown in the right-hand figure below. States where the agent is at a junction or at the location of a power pill are represented as nodes, and are labelled with letters; agent actions are represented as arcs, and labelled with action costs. The agent's current state is represented by node L. Assume the agent's current goal is to reach a power pill: goal states are represented by nodes B and M.





(a) To find a path to a goal state, your agent executes a depth-first search of the state-space graph, placing nodes onto the fringe in alphabetical order, only adding nodes to the fringe the first time they are encountered, and terminating when the first goal state is encountered.

(i) Draw the search tree created by this search algorithm. (3)

(ii) What sequence of nodes will the agent traverse when travelling the path your algorithm finds? (1)

(b) A depth-first search is not **optimal**. Describe what an optimal search is, and explain why the search executed in part (a) is not optimal. (3)

(c) Define (using pseudocode) a search algorithm which is optimal for the Pacman navigation task illustrated above. Your algorithm should be optimal whatever start and goal states are chosen, and should take into account path costs. (5)

2. **Logic and Knowledge Representation**

In 2050, security for the Hyde St party is provided by intelligent robots. A student, Martin, attempting to enter the party, makes the following argument to the robot, consisting of two premises (P1 and P2) and a conclusion (C).

P1. Every person who lives in Hyde St has a ticket to the party.
P2. Martin lives in Hyde St.
C. Therefore Martin has a ticket to the party.

(a) The above argument relies on an **implicit premise** P3. State the implicit premise in words. (1)

(b) Express the three premises P1...P3 and the conclusion C in first-order predicate logic. (Remember to use capitals for object constants and small letters for variables.) (4)

(c) Express the three premises and the negation of the conclusion in clause form. (2)

(d) Use **resolution refutation** to prove that the conclusion follows from the premises, indicating any variable bindings which you make. (2)

(e) Acquiring and representing common-sense knowledge is a stumbling block for many AI systems. How might an intelligent robot acquire the implicit premise in the above argument? (3)

3. **Natural language**

A linguist reading a romantic novel encounters the following three sentences.

S1. Reginald worked in the library.
S2. The assistant in the library was pretty.
S3. Reginald kissed the assistant in the library.

The linguist writes a small grammar to analyse the sentences.

s → np, vp	pn → Reginald
np → pn	det → the
np → det, n	n → library
np → np, pp	n → assistant
vp → v0	v0 → worked
vp → v1, np	v1 → kissed
vp → vwas, adj	vwas → was
vp → vp, pp	adj → pretty
pp → p, np	p → in

(a) Use the grammar to give syntactic analyses for sentences S1 and S2. (2)

(b) Sentence S3 is **syntactically ambiguous**: it has two different analyses.

(i) State in unambiguous language what the two interpretations of the sentence are. (2)

(ii) Give the two syntactic analyses of the sentence which the grammar permits, and say which analysis corresponds to which interpretation. (3)

(c) The grammar above permits an infinite set of sentences to be generated. Explain two ways in which this can happen, giving example sentences to illustrate. (2)

(d) What additional rules would be needed to allow the grammar to analyse the following sentences:

(i) Reginald believed the assistant loved him. (1)

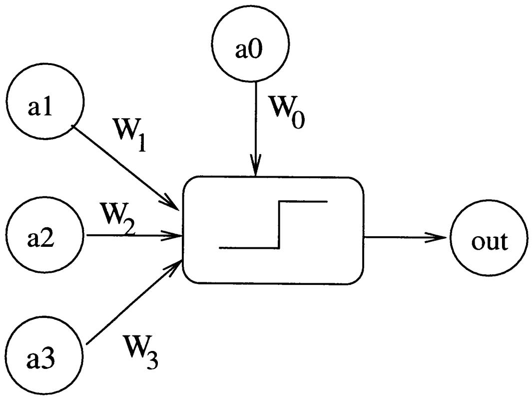
(ii) Every assistant in the library was pretty. (1)

(iii) Reginald was very very very very pretty. (1)

4. **Machine learning**

Your car is equipped with a binary perceptron, for use at traffic lights, to decide whether it can safely move forward (out=1) or not (out=0), based on various environmental facts which it can sense.

The perceptron has four inputs, a_0, a_1, a_2, and a_3:



- a_0 is a bias always set to -1
- a_1 holds information about green light (1 means 'yes', 0 means 'no')
- a_2 holds information about being at the front of queue (1 means 'yes', 0 means 'no')
- a_3 holds information about any pedestrians crossing in front of the queue (1 means 'yes', 0 means 'no')

Each input is multiplied by its associated weight, and the products are summed, i.e. total input $in = \sum W_i a_i$. If the result is greater than 0, i.e. $in > 0$, the output of perceptron $out = 1$, otherwise $out = 0$.

(a) Using all attributes, i.e. GreenLight (a_1=1 or 0), FrontOfQueue (a_2=1 or 0), and PedestriansCrossing (a_3=1 or 0), and using your commonsense knowledge about traffic light scenarios, create a table of all 8 training examples, e.g.: (2)

a_1	a_2	a_3	out
1	1	1	0
1	1	0	1
...	...	...	etc.

(b) State the definition of a linearly separable problem. Is this problem linearly separable? Use a geometric illustration to support your claim. (3)

(c) Write pseudocode for the algorithm which trains this binary perceptron. Include in it an equation for calculation of an error signal delta and an equation for the cumulative error for all examples from the training set. (5)

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

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

5. **Optimisation**

You are about to embark on an exploratory journey around the Polynesian triangle, starting from and returning to Aotearoa. You want to make a stop at all major islands or island archipelagos as depicted in this map:

Your resources are limited and therefore you want to optimise the total length of your round-trip journey so that you cover the least possible distance. Assume you know distance between each pair of islands. Use simulating annealing to optimise the total length L of your journey.

(a) Using the idea of an objective function landscape, describe what is the goal of optimisation. In your answer use the notions of local and global optima of an objective function. (1)

(b) Using the previous picture of objective function landscape explain how simulated annealing works to achieve a global optimum. (1)

(c) What is the control parameter T good for? (1)

(d) Does the value of T stay constant or does it change? If yes then how? (1)

(e) How would you calculate the objective function in the case of your round trip around Polynesia? (1)

(f) How would you code your (any) solution of the problem? (1)

(g) How would you generate an initial starting solution? (1)

(h) How would you generate the next solution of the problem? (1)

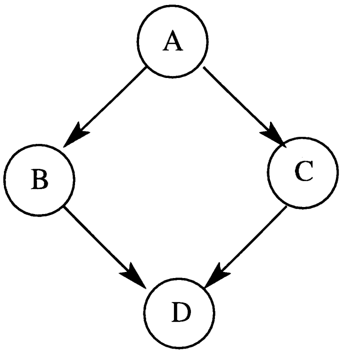
(i) Write pseudocode for simulated annealing algorithm for optimisation of the total length L of your journey. (4)

6. **Bayesian networks and probabilistic reasoning**

An auditor in a company is trying to determine the probability that an admitted applicant is really qualified for a job. The relevant probabilities are given in the Bayesian network shown here:

P(A)	P(neg A)
0.5	0.5

A	P(B $\mid$ A)	P(neg B $\mid$ A)
T	1.0	0.0
F	0.5	0.5



A	P(C $\mid$ A)	P(neg C $\mid$ A)
T	1.0	0.0
F	0.5	0.5

B	C	P(D $\mid$ B ^ C)	P(neg D $\mid$ B ^ C)
T	T	1.0	0.0
T	F	0.5	0.5
F	T	0.5	0.5
F	F	0.0	1.0

- A = applicant is qualified
- B = applicant has high grade point average
- C = applicant has excellent recommendations
- D = applicant is admitted

(a) Calculate the probability that an applicant is admitted given that he/she is qualified. (I.e. calculate $P(D|A)$.) Show your working. (3)

(b) Calculate the probability that an applicant is admitted. (I.e. calculate $P(D)$.) Show your working. (3)

(c) Calculate the probability that an admitted applicant is actually qualified. (I.e. calculate $P(A|D)$.) Show your working. (3)

(d) How would you estimate this latter probability, i.e. $P(A|D)$ using the method of approximate inference by rejection sampling based on evidence? (3)