THE UNIVERSITY OF HONG KONG

FACULTY OF ENGINEERING
DEPARTMENT OF COMPUTER SCIENCE

CSIS0270/COMP3270 ARTIFICIAL INTELLIGENCE

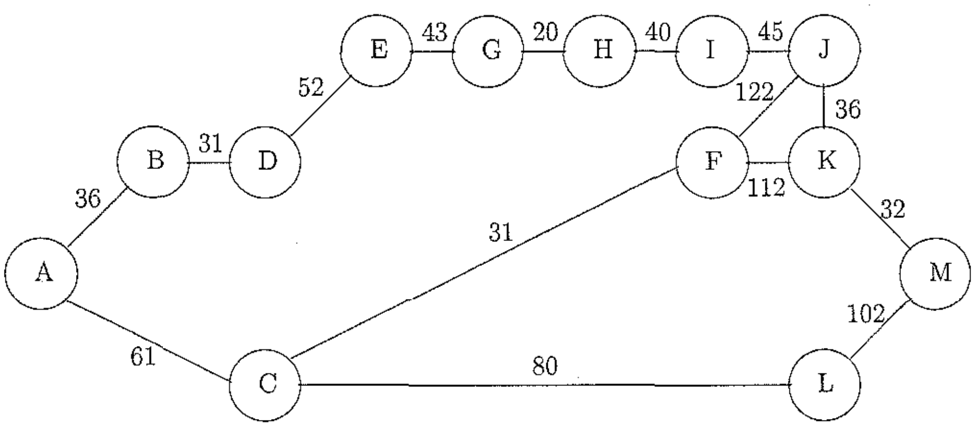
Date: 12 Dec 2015 Time: 2:30pm – 5:30pm

Only approved calculators as announced by the Examinations Secretary can be used in this examination. It is the candidate's responsibility to ensure that their calculator operates satisfactorily, and candidates must record the name and type of the calculator used on the front page of the examination script.

Instructions:

- This paper contains 6 questions on 6 pages.
- The mark for each question is enclosed in a pair of square brackets after the questions.
- Answer ALL questions.
- Total Mark is 100.

1. The graph below shows a map connecting various cities. The nodes represent cities, and the edge between nodes represent the road and the distance between them. The straight line distance from the target city M, is given in the table below. A* algorithm is used to find the shortest path from city A to M.



node	A	B	C	D	E	F	G	H	I	J	K	L	M
h	223	222	166	192	165	136	122	111	100	60	32	102	0

(a) Apply the A* algorithm on the above graph, filling in the table with (f, g, h) after the node name. The first two lines are filled as example. If you find a new path to a node already on the queue, update its cost (using the lower f value) instead of adding another copy of that node to the queue. Keep the queue sorted. [8]

Iteration	Node Expanded	Sorted Queue, $Node(f, g, h)$
0	–	A(223,0,223)
1	A	C(227,61,166), B(258,36,222)
2	?	...

(b) For the solution found by A*, give the cost and sequence of nodes comprising the path. [3]

(c) The A* algorithm is optimal when the heuristic used is *admissible*. Explain what is an admissible heuristic, and argue that with an admissible heuristic, A* is optimal. [4]

(d) A relaxed problem of the original problem can be used as a source for admissible heuristics. The original problem for 8-puzzle is such that:

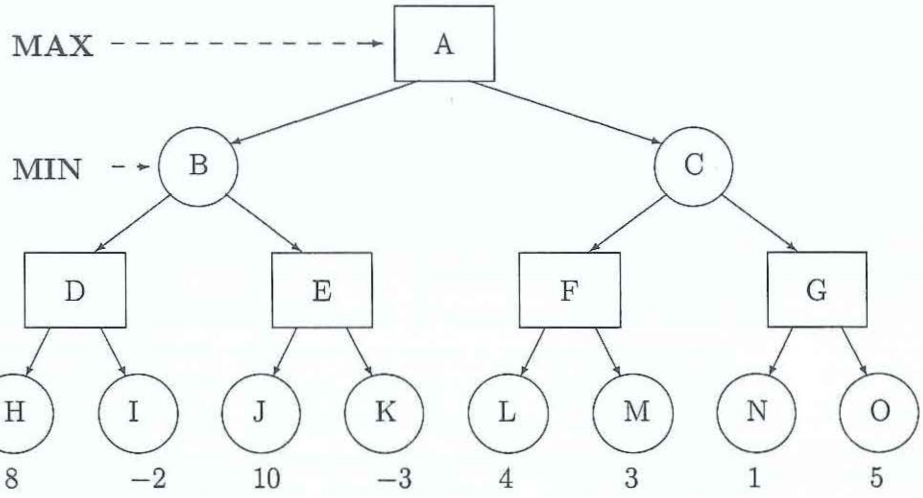
> a tile can move from square A to square B if A is horizontally or vertically adjacent to B and B is blank.

Explain what are the relaxed problems for the following heuristics for 8-puzzle, and why they are admissible heuristics: [4]

(i) the number of misplaced tiles.

(ii) the Manhattan distance between a tile and its desired position.

2. Given the following game tree, where a rectangle represents a max node, and a circle represents a min node. The evaluation of the node is positive for you if you win by the margin indicated by the value, and negative for your opponent.



(a) Apply minimax procedure to this game tree. Write down the evaluation function of all nodes in the tree. [4]

(b) If both party plays perfectly, write down who will win, and the path of play leading to this result. [2]

(c) Apply α-β pruning to this game tree. Draw the resultant search tree that is built by this algorithm. Remember to show the place where α-cut or β-cut occurs. [4]

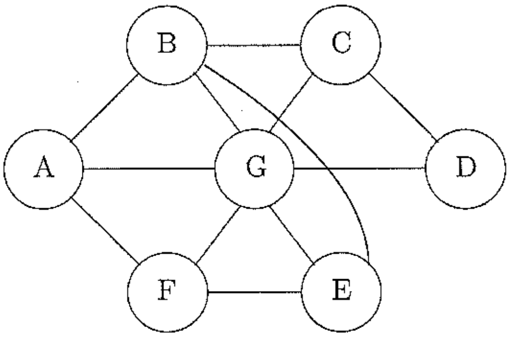
(d) The above game tree applies to deterministic games. However, there are games that involve chances.

(i) Give an example of chances in a game. [1]

(ii) How can you modify the game tree to incorporate chances. [2]

(iii) It is known that as long as the order of evaluation function is preserved, minimax procedure will produce the same result. Is it also true for games with chance? Briefly explain. [3]

3. (a) Color the following graph using only red, green and blue so that any two adjacent nodes (connected by an edge) have different colors. During the coloring process, variables are chosen by *minimum remaining values* (*MRV*), and *degree* heuristics, and their values by *least constraining value* (*LCV*) heuristics. If there is a tie in choosing a region to color, choose in alphabetical order. If there is a tie in choosing a color, then choose in the order red, green and then blue.



(i) Explain what are *minimum remaining values* heuristics, *degree* heuristics and *least constraining value* heuristics. [6]

(ii) In solving CSP, we use *forward checking* to reduce the domain size. Explain what is *forward checking*. [2]

(iii) Color the above map by filling the following table. Each stage contains the steps assigning a color to a variable, then followed by forward checking. Circle the color of the already assigned variable, and show the current domains of the unassigned variables (i.e. their legal colors) after each steps. The first assignment has been done for you. (Bold face is used in the table for chosen color, instead of circle for easy formatting) [8]

	A	B	C	D	E	F	G
Initial Domain	R G B	R G B	R G B	R G B	R G B	R G B	R G B
1st assign+*FC*	**R**	G B	R G B	R G B	R G B	G B	G B
2nd assign+*FC*							
...							

(b) Formulate the 2×2 Sudoku as a constraint satisfaction problem. The 2×2 Sudoku is similar to Sudoku except that the size of the square is reduced from 9×9 to 4×4 and there are four 2×2 square in it. State what are the variables, the domain and the constraints. [4]

4. Consider the following sentences:

   1. If there is gas in the tank and the fuel line is okay, then there is gas in the engine;
   2. If there is gas in the engine and a good spark, the engine runs;
   3. If there is power to the plugs and the plugs are clean, a good spark is produced;
   4. If the battery is charged and the cables are okay, then there is power to the plugs.

   (a) Convert the above rules to Conjunctive Normal Form using proposition symbols such as GasInTank, FuelLineOK, GasInEngine, etc. [4]

   (b) Suppose that you are given the facts that there is gas in the tank, the battery is charged, the fuel line and cables are both okay, and the plugs are clean. Using resolution, prove that the engine runs. [3]

   (c) Are the four rules above Horn clauses? Explain why or why not. If not, rewrite them as Horn clauses. Construct an AND-OR graph for the Knowledge Base. [4]

   (d) Prove the engine runs using Forward Chaining on the AND-OR graph. [3]

5. Consider the following information in the knowledge base:

   1. If a person is the mother of another person, then she is the parent of that person.
   2. If a person is the parent of another person, and he/she is alive, then he/she is older than that person.
   3. Mary is the mother of Susan.
   4. Mary is alive.

   (a) Represent the text in First-Order Logic. [4]

   (b) Convert the FOL sentences to Conjunctive Normal Form. Show all steps. [3]

   (c) Show that "Mary is older than Susan" using Resolution. Write down the substitution involved. [4]

   (d) Convert the following first-order logic sentence to CNF. What is the name of the process of removing existential quantifier bounded by universal quantifier? [3]

$$\forall x \;\; [\exists y \; f(y) \wedge g(x,y)] \Rightarrow [\exists z \; h(x,z)]$$

6. (a) Given the following joint distribution:

	toothache		¬ toothache	
	catch	¬ catch	catch	¬ catch
cavity	0.1	0.02	0.08	0.01
¬ cavity	0.02	0.01	0.2	0.56

Find the probability distribution $\mathbf{P}(Cavity|toothache)$ and $\mathbf{P}(Cavity|\neg toothache)$. [5]

(b) Construct a decision tree from the following examples: [5]

Example	A_1	A_2	A_3	Output y
1	1	0	0	0
2	1	0	1	0
3	0	1	0	0
4	1	1	1	1
5	1	1	0	1

(c) Argue that without nonlinear elements, a multi-layer neural network is equivalent to a single-layer neural network. What is the decision surface corresponding to a single-layer neural network? [5]

(d) What is the assumption made on the features for Naive Bayes Classifer? [2]

END OF PAPER