Artificial Intelligence

Final Exam, Spring 2016

Date: May 16, 2016 **Marks:100** **Time: 180 min.**

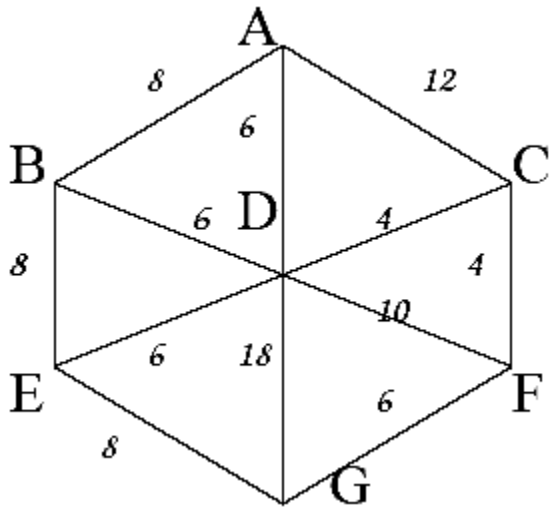
Note: Q[1 - 5] are same for ALL sections and Q6 is separate for each section.

Q1: Search Strategies:

[20 marks]

a) The numbers in the graph below are the real distances between the nodes. The estimated distances to the goal node, **G,** are the following:
A: 18, B: 13, C: 8, D: 18, E: 5, F: 6

A is the start node



1) What path would **breadth-first** search return for this search problem and also mention the nodes in the fringe **(i.e. Open List)** after the goal is found? .Ignore the costs and break the ties in alphabetical order. [**4 Marks**]

2) Apply **best first** search algorithm and also mark on the search tree, the order in which the nodes are expanded.[**6 Marks**]

b) Here is the simplified version of Sudoku game. Each cell can have the number 1,2,3,4 in 4x4 grid. Your task is to fill the grid with numbers, one cell at a time, in such a way that that there should be no repetition of a number in a row or a column. For example, the following figure (left) is invalid board configuration as the number 2 is repeated twice in the same row (row number 1) and it is repeated again in the last column. Same is the case for number1.

2	1	3	2
1	2	4	3
1	3	2	4
3	4	1	2

Invalid configuration

	3	2	1
3		1	4
2	1		3
1		3	2

initial configuration

1. Define a suitable heuristic function for this problem? [**2 Marks**]
2. Compute the value of your heuristic function for the initial configuration shown above. [**1 Marks**]
3. Apply A* search algorithm (graph search) to solve the above problem. Build the search tree and clearly indicate the order in which each state is expanded. [**7 Marks**]

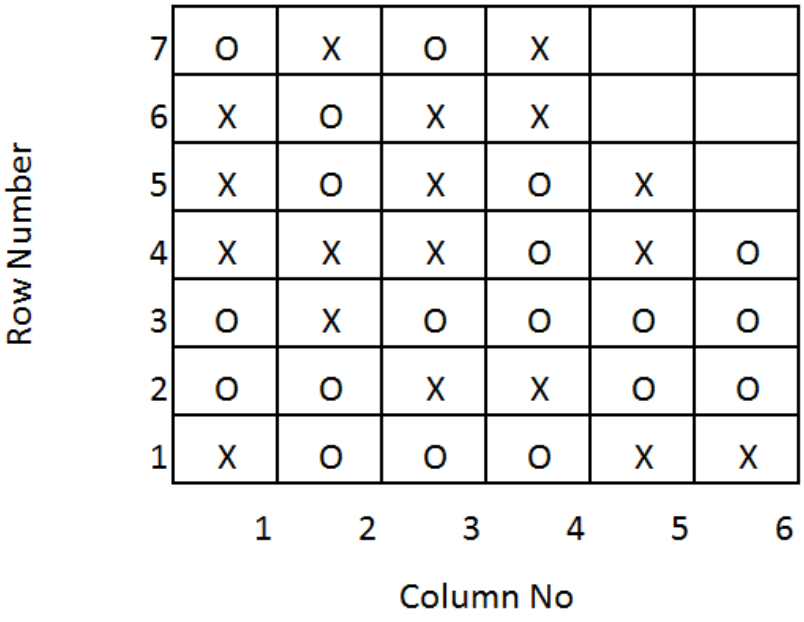
Q2. Adversary Games **[20 marks]**

Connect Four is a two-player connection game in which the players first take turns dropping marked discs (**Marked X disc** for computer player and **Marked O disc** for human player) from the top into a **seven-column, six-row** vertically suspended grid. The pieces fall straight down, occupying the next available space within the column.

The objective of the game is to **connect four** discs of the **same mark** next to each other **vertically**, **horizontally**, or **diagonally** before your opponent.

After taking the exciting course of AI at FAST some of our students have implemented an auto-player of connect-4 that uses MINIMAX algorithm with alpha-beta pruning to play the game.

While playing the game the auto-player (marking **X**) reached the following board position and it is his turn to make a move.



Part a) **[6 Points]**

Draw a complete game tree that will be used by the auto-player to make the move. You don't have to show the whole grid at every node of the tree, just show the mark and position being filled.

Part b) **[8 Points]**

Use the MINIMAX algorithm to determine the move of auto-player.

Part c) **[6 Points]**

Which part of the tree will be pruned by the auto-player if he always expand the nodes from left to right in your game tree.

Q3. Consider the problem of finding the shortest route through several cities, such that each city is visited only once and in the end return to the starting city (the Travelling Salesman problem). Suppose that in order to solve this problem we use a genetic algorithm, in which genes represent links between pairs of cities. For example, a link between London and Paris is represented by a single gene 'LP'. Let also assume that the direction in which we travel is not important, so that LP = PL**. [5+5 Marks]**

a) How many genes will be used in a chromosome of each individual if the number of cities is 10?

b) How many genes will be in the alphabet [Total number of genes to encode all pairs] of the algorithm?

Q4. Suppose a genetic algorithm uses chromosomes of the form x = abcdefgh with a fixed length of eight genes. Each gene can be any digit between 0 and 9. Let the fitness of individual x be calculated as:

$f(x) = (a + b) - (c + d) + (e + f) - (g + h)$, and let the initial population consist of four individuals with the following chromosomes:

x1 = 6 5 4 1 3 5 3 2

x2 = 8 7 1 2 6 6 0 1

x3 = 2 3 9 2 1 2 8 5

x4 = 4 1 8 5 2 0 9 4

a) Evaluate the fitness of each individual, showing all your workings, and arrange them in order with the fittest first and the least fit last. [4 Marks]

b) Perform the following crossover operations: [3 Marks]

i) Cross the fittest two individuals using one–point crossover at the middle point.

ii) Cross the second and third fittest individuals using a two–point crossover (points b and f).

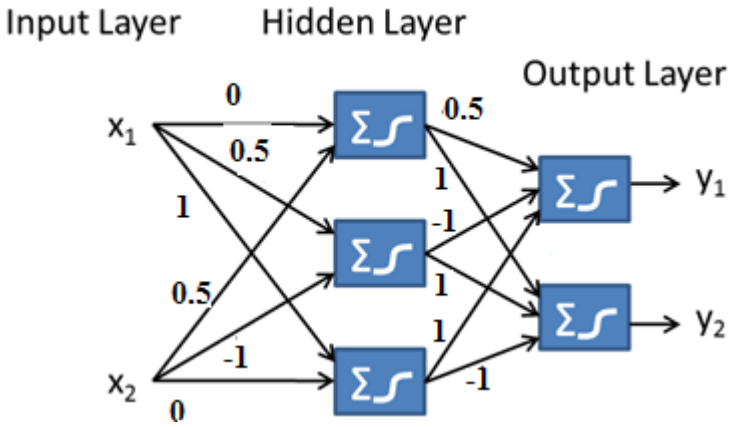
iii) Cross the first and third fittest individuals (ranked 1st and 3rd) using a uniform crossover.

c) Suppo se the new pop ulation consists of the six o ffspring individuals received by the crossover operations in the above question. Evaluate the fitness of the new population, showing all your workings. Has the overall fitness improved? [3 Marks]

Q5. Artificial Neural Network

Part a) Learning a feed-forward ANN

Consider the neural network architecture with two inputs **(x_1, x_2)** three hidden layer neurons and two o utput neurons (***Y_1, Y_2***). Assume that each neuron has a bias term set equal to -1 and each neuron uses the sigmoid activation function given as $f(x) = \frac{1}{1+e^{-x}}$



Weights of all neurons as shown on the figure are

Hidden Neurons

Top Neuron	**0**	**0.5**
Middle Neuron	**0.5**	**-1**
Bottom Neuron	**1**	**0**

Output Neurons

Top Neuron	**0.5**	**-1**	**1**
Bottom Neuron	**1**	**1**	**-1**

For the training example with input $\boldsymbol{X}$ = [1, 1] and Target $\boldsymbol{Y}$ = [0, 1]

i. Compute Output: **[3 Points]**

compute the neural network output where α = 1

ii. Error Calculation and Back Propagation. **[3 + 3 Points]**

a. For each of the output neurons, compute the error term $\boldsymbol{\delta_k}$ used by the back-propagation algorithm to update the weights.

b. Compute the error term $\boldsymbol{\delta_h}$ for each of the hidden neurons.

iii. Weight Update. **[6 Points]**

Use the errors computed above to compute the updated weights of the neural network. Take the value of learning rate η = 0.5.

Part b) Delta Rule Derivation **[5 Points]**

Consider a single perceptron unit with a bias term and ***n*** **inputs** [$x_0, x_1, \ldots x_n$]. The perceptron uses weights [$w_0, w_1, \ldots w_n$] and the sigmoid activation function (i.e. $f(x) = \frac{1}{1+e^{-x}}$) to compute the output.

Derive the weight update equation for such a perceptron using the following definition of **Error** $= \sum_j^m (y_j - y_j^*)^2 + \sum_{i=0}^n w_i^2$

where y_j is the target output and y_j^* is the output computed using weights and the activation function of neuron

Hints:

- Derivative of sigmoid activation function can be written as

  $f'(x) = f(x) \cdot (1 - f(x))$

- Weights are updated using the equation

$$W_i = W_i - \eta \Delta E_i$$

Therefore, to derive the final equation you need to compute the derivative of Error with respect to each of the weights components w_i and then use the weight update equation given above to derive the final equation.

Q6. [For Section C] a. Suppose, there are 9 rules in a **fuzzy expert system**, out of which 3 rules fire for a certain set of input conditions. The output parameter Y has the following membership values for these 3 rules:

Y' = 0/100, 0.25/200, 0.5/300, 0.75/400, 1/500, 0.85/600, 0.5/700, 0.25/800, 0/900, 0/1000
Y' = 0.6/100, 0.75/200, 0.75/300, 0.85/400, 1/500, 0.75/600, 0.5/700, 0.25/800, 0/900, 0/1000

Y' = 0/100, 0/200, 0/300, 0.75/400, 0.75/500, 0.75/600, 0.5/700, 0/800, 0/900, 0/1000

What will be the unified value of the output? [6 marks]

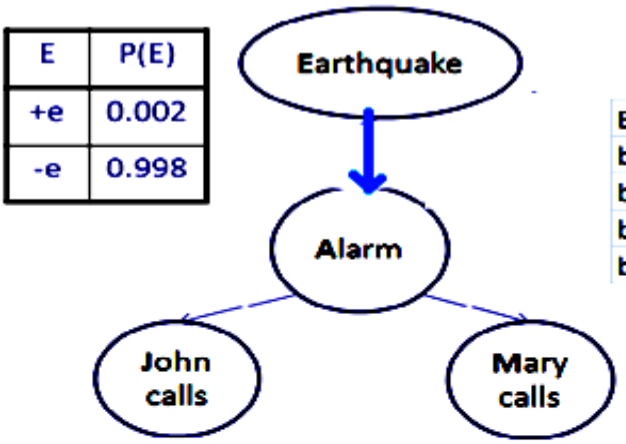
b. Find the intersection, union and complements of fuzzy sets A & B: [4 marks]

A = {0/10, 0.6/20, 1/30, 1/40, 0.3/50, 0.1/60, 0/70, 0/80, 0.5/90, 1/100}

B = {1/10, 0.5/20, 0/30, 0/40, 0.1/50, 0.3/60, 1/70, 1/80, 0.6/90, 0/100}

c. Draw a flow chart of CBR [Case Based Reasoning] System. Explain the main modules of WEKA?
[5+5 Marks]
d. Design a Multi Agent-based solution for monitoring, controlling and managing Lahore Road Traffic System. Draw a system architecture diagram to show each module of the proposed system. What are different agents and how they communicate with each other? [5+5 Marks]

Q6: [For Section A & B] Belief Network



E	P(E)
+e	0.002
-e	0.998

B	A	P(A|B)
b+	a+	0.95
b-	a+	0.1
b+	a-	0.05
b-	a-	0.9

A	J	P(J|A)
+a	+j	0.9
+a	-j	0.1
-a	+j	0.05
-a	-j	0.95

A	M	P(M|A)
+a	+m	0.7
+a	-m	0.3
-a	+m	0.01
-a	-m	0.99

Part a) **[4 points]**

Use the belief network given above to compute probabilities of the joint probability distribution of the four variables assuming that each variable can take only two different values.

Part b) **[2 + 2 + 3 points]**

Compute the following

i. P(+b | +j, +m)
ii. P(-b | -m, +j).
iii. Marginal distribution of variables E, A, and M

Part c) **[3 Points]**

By computing some appropriate probabilities show which of the following pair of variables are independent of each other.

i. J and M
ii. M and A
iii. A and M

Part d) **[3 Points]**

The network shown above encodes certain conditionally independence assumptions. List all independence assumptions that one can directly read from the network shown above.

Part e) Naive Bayes **[3 Points]**

Consider training the Naive Bayes model shown on the left with the training data provided in the table on the right.

(i) Estimate the estimate of $P(F_1 = 1 \mid Y = 0)$ without using smoothing.
(ii) Assuming Laplace smoothing with k = 1, the est

Q6. [For Section D] Fuzzy K-mean **[10+10 Marks]**

a) Perform one iteration of Fuzzy K-mean for the given data. (Calculation of centroid and updating of membership)

X	Y	m_1	m_2
1	0	0.8	0.2
2	1	0.9	0.1
3	2	0.7	0.3
4	4	0.3	0.7

The data is portioned into two cluster. m_1 and m_2 represent the membership of each data point. Assume r=2.

b) FAST Student made a classifier which predict the mood of a person. The mood of the persons are divided into three categories i.e. happy, sad and angry. They test their classifier on 10 persons which make the following predictions.

Real Mood	Predicted Mood
Sad	Happy
Sad	Angry
Sad	Sad
Sad	Sad
Happy	Angry
Happy	Happy
Angry	Angry
Angry	Sad
Angry	Happy
Angry	Angry

First column represents the real mood of person and 2nd column represent the mood predicated by machine.

Draw the confusion matrix for the above data.

1) Calculate the precision and accuracy of the data.