School of Information Technology
Indian Institute of Technology Kharagpur

Soft Computing Applications :: IT60108
End-Semester Test
(*Spring Semester, Session 2013-2014*)

Full Marks: 100 **Time: 03 Hours**

Instruction: *Answers to all parts of a question must be placed together*

1. A virtual keyboard (also called *on-screen graphics* keyboard) has to be designed for composition of text in a language L say. The language L consists of a set of alphabets A_L. The problem in the virtual keyboard design is to arrange the alphabets A_L in a special arrangement such that text entry rate is *maximum.* The text entry rate, say T is defined as $T= f(d_{ij}, p_{ij})$ for $i, j = 1, 2, \ldots, |A_L|$ where d_{ij} denotes the distance between any two i-th and j-th alphabets and p_{ij} denotes the probability that the j-th alphabet will occur after the i-th character, $|A_L|$ denotes the size of the set of alphabets.

The virtual keyboard has to be designed with a constraint as below.
It is observed that all alphabets in A_L can be categorized into three categories according to their occurrences in any text: highly frequent, frequent and less frequent. The alphabets are to be placed in three zones according to their frequency of occurrences (see **Fig. 1**).
Further, any two alphabets $a, b \in A_L$ should be placed in the layout in such a way that the distance between a, b is minimum along with their digraph probability and hence T is maximum.

It is proposed to find an optimal arrangement of alphabets in the layout of the virtual keyboard using Genetic Algorithm(GA) satisfying the above constraints. Answer the following while solving the problem with GA.

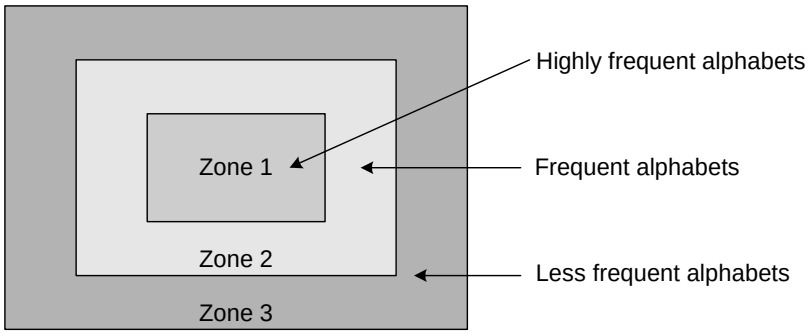


Figure 1

a) What sort of GA encoding you should think to solve the problem? Justify your answer. 2

b) Decide the structure (genotype) of the chromosome. 2

c) Discuss a suitable crossover mechanism for this problem with an illustration. 2+2

d) Suggest a selection strategy to solve the problem. 4

e) What procedure you should follow to make the selection pressure high and population diversity is large? 4

2. **a)** **Figure 2(a)** shows the membership function $\mu_A(x)$ of a fuzzy set A defined on a universe of discourse X.

i. Mark the core, crossover point(s) and support of the fuzzy set A. 3

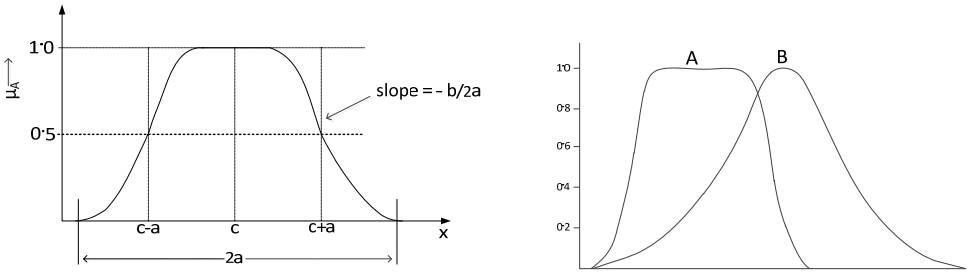
ii. With the parameters given in Fig. 2(a), formulate $\mu_A(x)$ as a *generalized bell MF*. 2

b) The membership functions of two fuzzy sets A and B is shown in **Fig. 2(b)**. Draw graphically the fuzzy sets for the following.

i. Intersection of A and B

ii. Union of A and B

iii. Compliment of A and B 4



(a) **(b)**

Figure 2

c) Let X and Y be two universes of discourses. A binary fuzzy relation R is defined in $X \times Y$ as below.

$$R = \{((x, y), \mu_R(x, y)) | (x, y) \in X \times Y\}$$

The membership function of the fuzzy relation R is defined as follows.

$$\mu_R(x, y) = \begin{cases} \dfrac{y - x}{x + y + 2} & \text{if } y > x \\ 0 & \text{if } y \leq x \end{cases}$$

i. Define $\mu_{\overline{R}}(x, y)$, where $\overline{R}$ denotes the complement of fuzzy relation R. 3

ii. If x = {3, 4, 5} and y = {3, 4, 5, 6, 7}, then express R, $\overline{R}$ in the form of relational matrices. 2+2

d) Let $R_1 = x$ *is relevant to* y and $R_2 = y$ *is relevant to* z be two fuzzy relations defined on $X \times Y$ and $Y \times Z$, where $X = \{1, 2, 3\}$, $Y = \{\alpha, \beta, \gamma, \delta\}$ and $Z = \{a, b\}$. R_1 and R_2 are expressed as shown in **Fig. 3**.

i. Express R_1 and R_2 in terms of their relation matrices. 3

ii. Compute $\mu_{R_1 \circ R_2}(2, a)$ where $2 \in X$ and $a \in Z$ using *Zadeh's max-min composition* and *T-norm's max-product*. 3+3

e) The fuzzy sets P and Q are defined on x as follows.

$\mu(x)$	x_1	x_2	x_3	x_4	x_5
P	0.1	0.2	0.7	0.5	0.4
Q	0.9	0.6	0.3	0.2	0.8

Find the following.

i. $P_{0.2}$ and $Q_{0.3}$ ii. $(P \cup Q)_{0.6}$ iii) $(P \cup \overline{P})_{0.8}$ 7

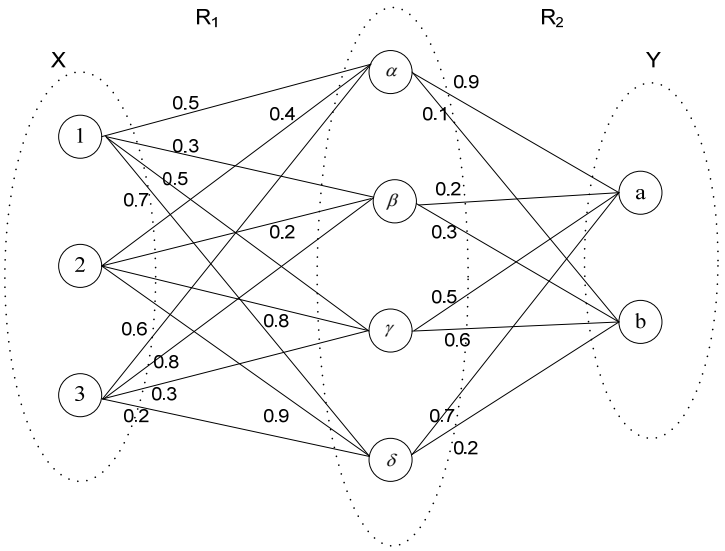


Figure 3

3. There are two inputs I_1 and I_2 and an output O of a process. It is required to develop a fuzzy logic controller (FLC) based on the *Mamdani approach*. The inputs and output are expressed using three linguistic terms namely *L* (low), *M* (medium) and *H* (high). The membership function distributions of the above inputs and output are shown in **Fig. 4**. The rule-base of the fuzzy logic controller is shown in **Table 1**.

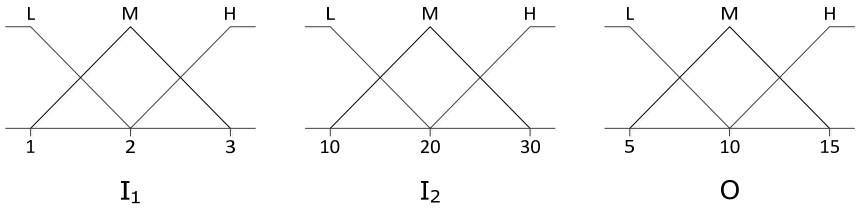


Figure 4

Table 1

		I_2		
		L	M	H
I_1	L	L	L	M
	M	L	M	H
	H	M	H	H

Suppose, at any instant, inputs to the fuzzy logic controller are $I_1 = 1.5$ and $I_2 = 25$.

a) Obtain the *fuzzified* values of the input. 4

b) Compute rule strengths of the rules corresponding to the given inputs. 4

c) Decide the fuzzy output for the given inputs. 4

d) *Defuzzyfying* the output using *Center of Sum* (COS) method. 4

4. **a)** Consider a problem which is defined over an input space of *N*-dimensions. Assume that all inputs to the problem are linearly separable with a continuous region bounded by an *M*-dimensional space.

i. What kind of neural network architecture you should consider to solve such a problem. Draw a schematic diagram of the proposed neural network. 3

ii. Supervised learning has been advocated to train the proposed network. Suppose, $T<I,O>$ denotes the training set of size *n*. Write an algorithm to train the network. 5

b) A *multiple layer feed forward neural network* (MLFFNN) is shown in **Fig. 5.** In Fig. 6, N^X denotes all neurons at layer *X*, $|N^X|$ denotes the number of neurons in the layer *X*, [*V*], [*W*] denote the weight matrices of the synapses connecting neurons between two adjacent layers, I^X and O^X denote the input and output of layer *X*, respectively.

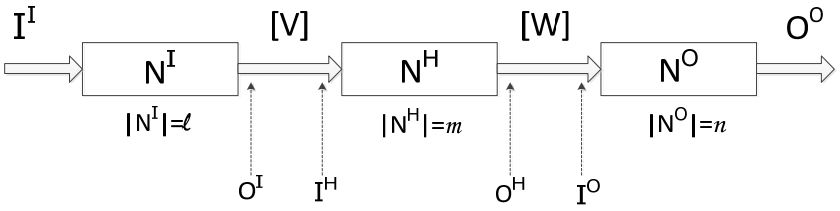


Figure 5

Assume that all neurons in N^I, N^H and N^O use *linear*, *log-sigmoid* and *tanh-sigmoid* transfer functions, respectively.

With reference to this MLFFNN, obtain the following:

i. Express [*V*] and [*W*] in matrix form 2

ii. Input and output of any

i-th neuron at input layer 2

j-th neuron at hidden layer 2

k-th neuron at output layer 2

5. Consider any multiple neural network with *V* and *W* are the weight matrices between input-hidden and hidden-output layer, respectively. Assume that error *E* of the neural network is varying with *V* and *W* when other parameters of the network remain constants. It is required to decide *V* and *W* for a given training data, so that the error *E* is minimized.

a) Using the *Steepest Descent method*, prove that 4

$$\Delta V = -\eta \frac{\partial E}{\partial V} \quad \text{and} \quad \Delta W = -\eta \frac{\partial E}{\partial W}$$

where η is a constant.

b) If E_k denotes an error of the *k*-th neuron at output layer and w_{jk} denotes the weight between the connection of any *j*-th neuron at hidden layer to the *k*-th neuron at the output and v_{ij} is the weight between the connection of any *i*-th neuron at the input layer to the *j*-th neuron of the hidden layer, then find the following using chain rules of differentiation. 6+6

$$\frac{\partial E}{\partial w_{jk}} \quad \text{and} \quad \frac{\partial E}{\partial v_{ij}}$$

[Clearly mention any assumption(s) you make in your calculation].

6. **a)** Explain your answer to the following with appropriate graphical illustrations.

i. Ideal objective vector 2

ii. Utopian objective vector 2

iii. Nadir objective vector 2

b) Draw the framework of Non-dominated Sorting Genetic Algorithm (NSGA). 3

c) In the context of NSGA, explain the following operations

i. Assigning dummy fitness value 3

ii. Sharing the fitness value 3

d) Mention any one limitations in NSGA and explain how the limitation is addressed in NSGA-II 1 4

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