University of Alberta
Dept. of Electrical and Computer Engineering

ECE449 Intelligent Systems Engineering

SAMPLE FINAL EXAMINATION

This sample final exam shows the overall structure of the exam and *types* of questions that can be expected, not *specific questions* or *contents* that will be covered in the actual exam.

Question(s)	Worth	Marks	Subject
I. (1-5)	10		Various multiple choice
II. (6-8)	10		Various short answer
III. (9-11)	30		Neural Networks
IV. (12-14)	30		Fuzzy Systems
V. (15-17)	20		Evolutionary Computing
Total	**100**		**-**

I. Various multiple choice [10 marks total]

1. [2 marks] Which of the following statements about lateral inhibition is TRUE:

☐ After the iterative process is completed, multiple neurons remain active
☐ Outputs of each neuron are fed back to its neighbors' inputs through negative weights
☐ Outputs of each neuron are fed back to its input through a negative weight
☐ Outputs of each neuron are fed back to its neighbors' inputs through positive weights
☐ Outputs of all neurons are fed back to the inputs of neurons in the previous layer

2. [2 marks] Which of the following relationships CANNOT be classified as a fuzzy relation:

☐ Age – marital status
☐ Similarity of integers from the interval [1, 5]
☐ Canadian province – provincial sales tax
☐ Gender – weight
☐ Processor speed – processor cost

3. [2 marks] The purpose of the momentum term added to backpropagation learning algorithm is to

☐ Linearize the dependency of weight change with respect to error
☐ Eliminate local minima on error surface
☐ Increase the learning step unconditionally
☐ Increase the learning step when gradient changes direction
☐ Decrease the learning step when gradient changes direction

4. [2 marks] In Kohonen self-organizing maps, weights in the neigbourhood of the winning neuron are updated

☐ To avoid overtraining
☐ To make resulting clusters larger
☐ To preserve topology of the input space
☐ To filter out small disturbances
☐ To facilitate self-organization

5. [2 marks] Which of the following statements is NOT true about fuzzy sets

☐ They are based on concept of gradual membership
☐ They can express linguistic descriptions
☐ They provide generalization of conventional (crisp) set theory
☐ They are based on theory of probability
☐ They can be described by a membership function

II. Various short answer [10 marks total]

1. [2 marks] Briefly explain the concept of *neural plasticity*

2. [5 marks] Fill in the blanks in the following table with appropriate words from the following list {inputs; outputs; weights; totals, targets}:

Percepron learning rule is based on comparing		and	
ADALINE learning rule is based on comparing		and	
Backpropagation learning rule is based on comparing		and	
Grossberg instar learning is based on comparing		and	
Grossberg outstar learning is based on comparing		and	

3. [3 marks] Name three selection procedures commonly used in genetic algorithms.

III. Fuzzy Systems [30 marks total]

4. [6 marks] Suppose variable x is defined on a discrete universe of discourse

$$X = \{0, 10, 20, 30, 40, 50\}$$

and that A is a fuzzy set on this universe of discourse defined as

$$A = \{A(x)|x\} = \{0.0|0 , 0.5|10, 1.0|20, 0.5|30, 0.0|40, 0.0|50\}$$

a) [2 marks] Sketch the membership function of fuzzy set A

b) [4 marks] Determine the following properties of fuzzy set A:

Height: Hgt(A) =

Support: Supp(A) =

Core: Core(A) =

Cardinality: Card(A) =

5. [6 marks total] Consider a fuzzy relation, R, defined in matrix form

$$R(x,y) = \begin{bmatrix} 1.0 & 0.4 & 0.8 & 0.3 & 0.0 \\ 0.5 & 1.0 & 0.6 & 0.7 & 1.0 \\ 0.9 & 1.0 & 0 & 0.6 & 0.8 \\ 1.0 & 0.5 & 0.2 & 0.0 & 0.9 \\ 0.3 & 0.5 & 0.3 & 0.1 & 1.0 \end{bmatrix}$$

a) [2 marks] Determine projections ProjR_x and ProjR_y of the relation R.

Proj$R_x(x)$ =

Proj$R_y(y)$ =

b) [2 marks] Reconstruct the relation from these projections using min ***t***-norm.

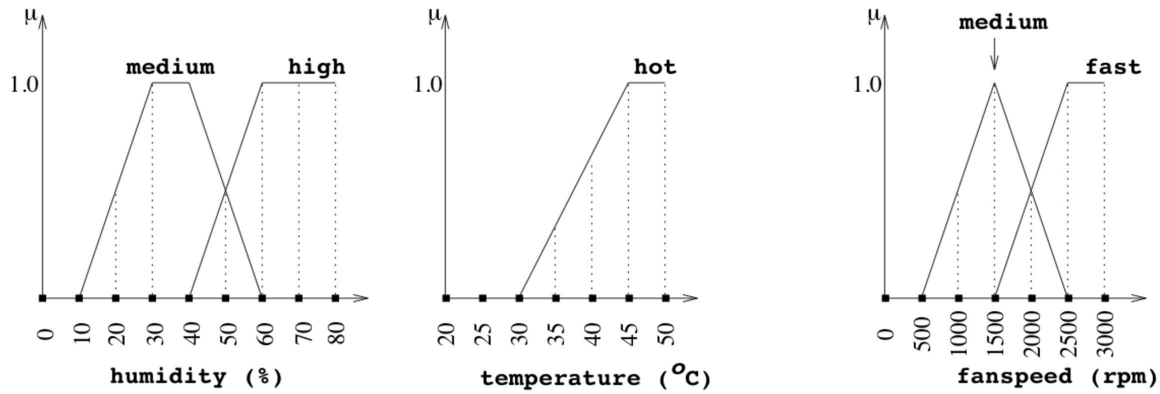
$R_{\text{rec}}(x, y) = \cdots$

c) [2 mark] Comment on quality of the reconstruction obtained in 10b).

6. [18 marks total] For a fuzzy controller with the following algorithm

IF `humidity` is `high` AND `temperature` is `hot` THEN `fanspeed` is `fast` ELSE
IF `humidity` is `medium` AND `temperature` is `hot` THEN `fanspeed` is `medium`

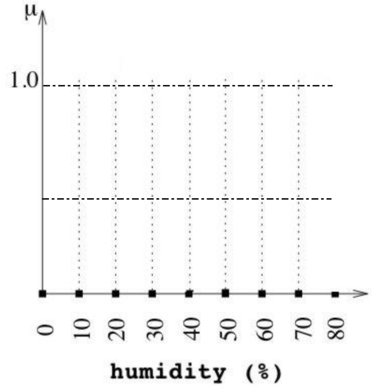
and with fuzzy sets defined as follows:

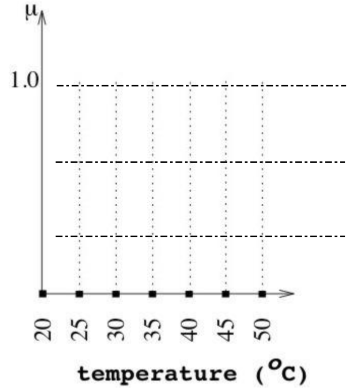


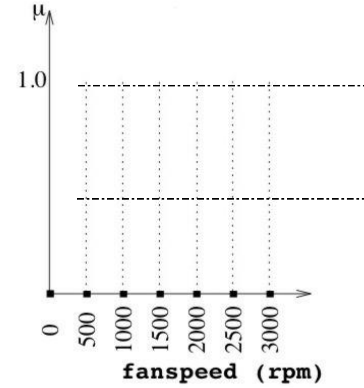
a) [8 marks] Using the axes provided on the following page, derive the output fuzzy set corresponding to crisp inputs of **`humidity`** = 50% and **`temperature`** = 40^{o}C using graphical method. Use **`min`** (Mamdani) inference, and **`min`** ***t***-norm as the interpretation of the AND within the antecedents.

b) [4 marks] Calculate the crisp `fanspeed` corresponding to the fuzzy set found in a) using the SCOA method.

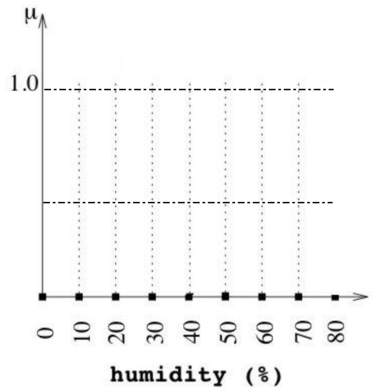
Rule 1:

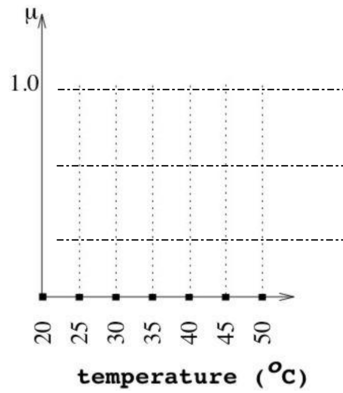


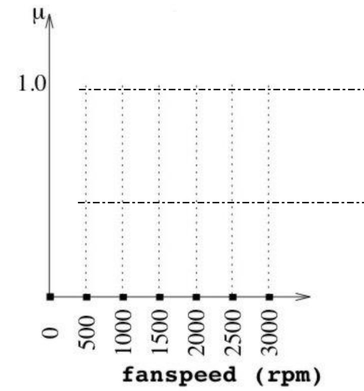




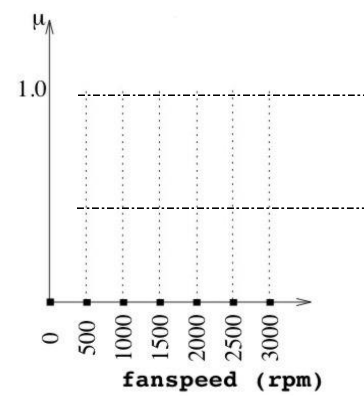
Rule 2:







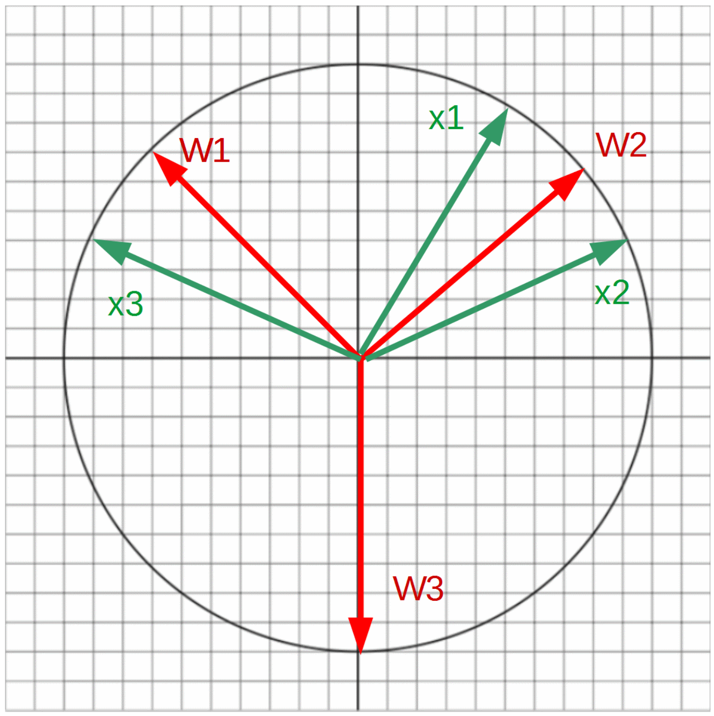
Output fuzzy set:



c) [6 marks] Comment on the expected performance of this controller [Hint: Use visual inspection to examine the static properties of the rule base.]

IV. Neural Networks [30 marks total]

7. [10 marks total] Consider a competitive network with two inputs and three neurons in the competitive layer. Plot of the input vectors and initial weights in a unit circle is provided below:



a) Determine the resulting weights (in terms of original weights and/or input vectors, i.e. not numerically) found after training with the competitive rule with learning rate $\eta = 1$, using the following sequence of training inputs: **x**(1), **x**(2), **x**(3) [3 marks]

Pattern presented	Winner ($\mathbf{w}_i$)	Winner updated to
x(1):		
x(2):		
x(3):		

Summary of weights after training
$\mathbf{w}_1 =$
$\mathbf{w}_2 =$
$\mathbf{w}_3 =$

b) Analyze the resulting weights for case a) and elaborate on the final weight distribution with respect to the input vectors: which patterns ($\mathbf{x}(k)$) are represented by which weight vectors ($\mathbf{w}_i$)? [3 marks]

$\mathbf{w}_1$ -

$\mathbf{w}_2$ -

$\mathbf{w}_3$ -

c) Consider that the sequence of training inputs was changed to $\mathbf{x}(3)$, $\mathbf{x}(1)$, $\mathbf{x}(2)$. Will the resulting set of weights be the same as in the case b) above? [2 marks]

Pattern presented	**Winner ($\mathbf{w}_i$)**	**Winner updated to**
$\mathbf{x}(3)$:		
$\mathbf{x}(1)$:		
$\mathbf{x}(2)$:		

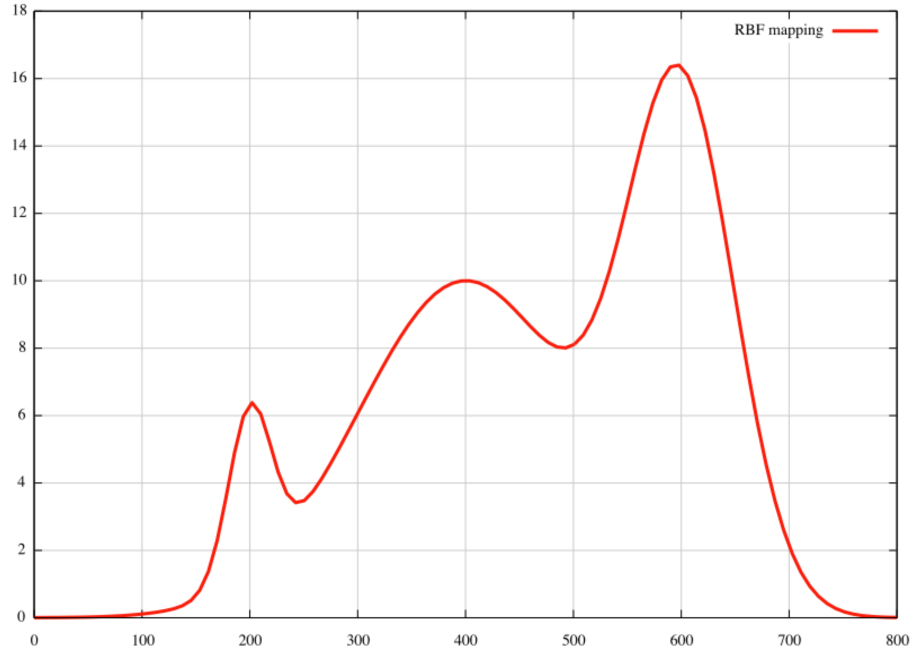
Summary of weights after training
$\mathbf{w}_1 =$
$\mathbf{w}_2 =$
$\mathbf{w}_3 =$

d) Consider that the sequence of training inputs was changed to $\mathbf{x}(3)$, $\mathbf{x}(2)$, $\mathbf{x}(1)$. Will the resulting set of weights be the same as in the case a) above? [2 marks]

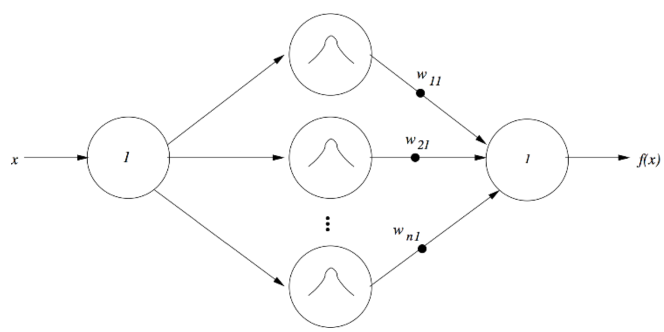
Pattern presented	**Winner ($\mathbf{w}_i$)**	**Winner updated to**
$\mathbf{x}(3)$:		
$\mathbf{x}(2)$:		
$\mathbf{x}(1)$:		

Summary of weights after training
$\mathbf{w}_1 =$
$\mathbf{w}_2 =$
$\mathbf{w}_3 =$

8. Derive a Radial Basis Function (RBF) network that generates the following function:



The network will have the following architecture:



The activation function of the output neuron is a linear function with no bias:

$$f(x) = \sum_{i=1}^{n} w_{i1} o_i ,$$

where n is the number of RBF nodes (determined by you), and o_i denotes the output from the i-th neuron in the hidden layer. Assume all n RBF nodes use Gaussian kernel function

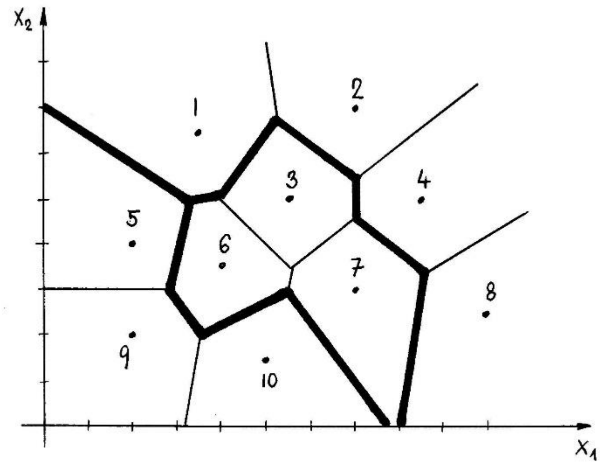
$$o_i = e^{-\frac{\|x - m_i\|^2}{2s^2}}$$

(a) How many RBF nodes are best-suited to generate $f(x)$? Explain why. [2 marks]

(b) Specify all parameters for the hidden layer nodes, i.e. centers of the basis functions μ_i and their standard deviations σ_i. The standard deviations can be expressed in terms of one-another. (e.g. $\sigma_i > \sigma_j > \sigma_k$). [4 marks]

(c) Derive approximate values of all weights (w_{11}, ..., w_{n1}). Note that although the weights are derived numerically in practice, graphical determination is possible here, based on the function plot. [4 marks]

9. Consider a partition obtained by a competitive layer of a neural network, dividing the feature space into ten regions outlined in the figure below, and represented by ten prototype vectors labeled 1-10.



The ultimate goal of the neural network is to aggregate regions 1-10 to three larger areas indicated by the thick lines in the figure.

a) [6 marks] Sketch the structure of a neural network that could be used to implement both parts of this problem (i.e. the initial partition into 10 regions using competitive layer, and the final partition into 3 larger regions using vector quantization layer); label each layer to indicate what its purpose is.

b) [3 marks] Which learning rule can be used to implement the initial partition into ten convex regions (name the rule and provide its mathematical description).

c) [3 marks] Write down the weight matrix that can be used to aggregate the convex regions into the three larger regions shown in the figure.

V. Evolutionary Computing [20 marks total]

10. [10 marks] Consider following population of N=6 individuals of a genetic algorithm

{[1, 1], [3, 2], [1, 6], [7, 4], [2, 3], [8, 6]}

Each individual represents a candidate solution in form [x, y] for a problem with integer parameters. The fitness function

$$f\,(x\,,y)=\max(|x-2|\;,\;|y-3|)$$

should be <u>minimized</u>.

a) [6 marks] Determine the intermediate population obtained using deterministic tournament method, assuming that the following groups of individuals have been formed for tournaments (the symbols represent individuals in the population listed above, starting with index "A" for the first individual on the left):

A-B, C-D, E-F, A-C, B-F, D-E

Individual	x	y	f(x,y)
A			
B			
C			
D			
E			
F			

Tournament		Winner	New [x,y]
A	B		
C	D		
E	F		
A	C		
B	F		
D	E		

b) [4 marks] Comment on the composition of the intermediate population from the perspective of counts of individuals it contains and their fitness.

11. [6 marks] Consider following two individuals of a genetic algorithm

[1.5, 0.1, 3.5, 2.2, 2.0, 5.5]
[1.5, 3.0, 4.2, 4.5, 3.5, 1.8]

Write down the resulting children obtained using

(a) Simple arithmetic recombination with parameters $k = 3$ and $\alpha = 0.6$

(b) Simple arithmetic recombination with parameters $k = 3$ and $\alpha = 0.6$

(c) Whole arithmetic recombination with parameters $k = 3$ and $\alpha = 0.6$

14. [4 marks] Consider the following schema: **`*1*110*`** Write down all individuals represented by this schema.

ECE449 FINAL EXAM – FORMULA SHEET

<u>Learning rules:</u>

Perceptron:	$Dw_i = hx_i(t-o)$
ADALINE:	$Dw_i = hx_i(t-tot)$
Instar:	$Dw_i = h(x_i - w_i)$
Outstar:	$Dw_{ij} = h(t_j - w_{ij})$
Competitive:	$k = \arg\min_i(\|x - w_i\|);Dw_{ik} = h(x_i - w_{ik})$

<u>Properties of fuzzy sets:</u>

Height:	Hgt(A) = $\sup_x A(x)$
Support:	Supp(A) = $\{x \in X \mid A(x) > 0\}$
Core:	Core(A) = $\{x \in X \mid A(x) = 1\}$
Cardinality:	Card(A) = $\Sigma_{x \in X} A(x)$

<u>Extension principle:</u>

$B(y) = \sup_{x=f^{-1}(y)} \min(A(x))$

<u>Fuzzy relations:</u>

Construction:	$R(x,y) = A(x) \times B(y) = \min(A(x), B(y))$
Projections:	$\mathrm{Proj}R_x(x) = \sup_{y \in Y} R(x,y)$, $\mathrm{Proj}R_y(y) = \sup_{x \in X} R(x,y)$
Cylindric extension:	Cyl (A) (x,y) = A(x) for all $y \in Y$

<u>Implication operators:</u>

Name	Implication operator $\Phi[A(x),B(y)]$	ELSE connectives
Mamdani (min)	$\min[A(x),B(y)]$	OR (**s**-norm)
Larsen (product)	$A(x) \cdot B(y)$	OR (**s**-norm)
Zadeh (max-min)	$\max\{\min[A(x),B(y)],1-A(x)\}$	AND (**t**-norm)
Lukasziewicz (arithmetic)	$\min[1-A(x)+B(y), 1]$	AND (**t**-norm)
Boolean (Dienes-Rescher)	$\max[1-A(x), B(y)]$	AND (**t**-norm)

<u>Defuzzification operators:</u>

$$b = \mathrm{COA}(B(y)) = \frac{\int B(y)y\,dy}{\int B(y)dy}; \quad b = SCOA(B(y)) = \frac{\sum B(y)\cdot y}{\sum B(y)}; \quad b = MOM(B(y)) = \frac{\alpha + \beta}{2}$$

<u>Arithmetic crossover:</u> parents are of length l, Parent 1: $\langle x_1, K, x_l \rangle$, Parent 2: $\langle y_1, K, y_l \rangle$

Simple:

$$\text{Child 1}: \langle x_1, K, x_k, [\alpha x_{k+1} + (1-\alpha) y_{k+1}], K, [\alpha x_l + (1-\alpha) y_l] \rangle$$
$$\text{Child 2}: \langle y_1, K, y_k, [\alpha y_{k+1} + (1-\alpha) x_{k+1}], K, [\alpha y_l + (1-\alpha) x_l] \rangle$$

Single:

$$\text{Child 1}: \langle x_1, K, x_{k-1}, [\alpha x_k + (1-\alpha) y_k], x_{k+1}, K, x_l] \rangle$$
$$\text{Child 2}: \langle y_1, K, y_{k-1}, [\alpha y_k + (1-\alpha) x_k], y_{k+1}, K, y_l] \rangle$$

Whole:

$$\text{Child 1}: x_i^{\text{new}} = \alpha x_i^{\text{old}} + (1-\alpha) y_i^{\text{old}}, \quad i = 1, 2, K, l$$
$$\text{Child 2}: y_i^{\text{new}} = \alpha y_i^{\text{old}} + (1-\alpha) x_i^{\text{old}}$$