Kingdom of Saudi Arabia Ministry of Education University of Jeddah College of Computer Science and Engineering Department of Computer Science and Artificial Intelligence	جامعة جدة University of Jeddah	المملكة العربية السعودية وزارة التعليم جامعة جدّة كلية علوم وهندسة الحاسب قسم علوم الحاسب والذكاء الاصطناعي

Assignement 2

CCAI 321 Artificial Neural Networks

First semester 2022/2023

Exam Date: Sunday 11/7/2023 **Exam Duration: 1 week**

Student Name: Rimas Nawi Alshehri **Student ID:** 2110240

Instructor Name	Section
Samia Snoussi	A2/AI

Instructions:

Please Turn Off your mobile phones

Cheating or discussion with colleagues will result in negative marking

Including this cover page, this exam booklet contains 3 pages. Check if you have missing pages

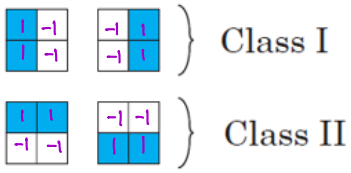
PLO/CLO	SO
PLO K1 (CLO 1): Demonstrate basic knowledge of mathematics and sciences to identify, analyze and solve problems related to relevant disciplines in neural network	**SO 1 :** Analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions
PLO K2 (CLO 2): Evaluate and **Classify** neural networks algorithms, processes and systems using modeling techniques	
PLO S1 (CLO 2): Design, **implement** and **evaluate** practical solutions to domain-specific problems against set of requirements in the context of neural network discipline	**SO 2 :** Design, implement, and evaluate a computing based solution to meet a given set of computing requirements in the context of the program's discipline

		Max Score	Student Score
PLO K1 / CLO 1 / SO 1	**Question 1**	**0.4**	
PLO K1 / CLO 1 / SO 1	**Question 2**	**0.4**	
PLO K1 / CLO 1 / SO 1	**Question 3**	**0.8**	

PLO K1 / CLO 1 / SO 1	**Question 4**	**2**	
PLO K1 / CLO 1 / SO 1	**Question 5**	**0.4**	
PLO K1 / CLO 1 / SO 1	**Question 6**	**0.2**	
PLO K1 / CLO 1 / SO 1	**Question 7**	**0.2**	
PLO K1 / CLO 1 / SO 1	**Question 8**	**0.4**	
Total		**5**	

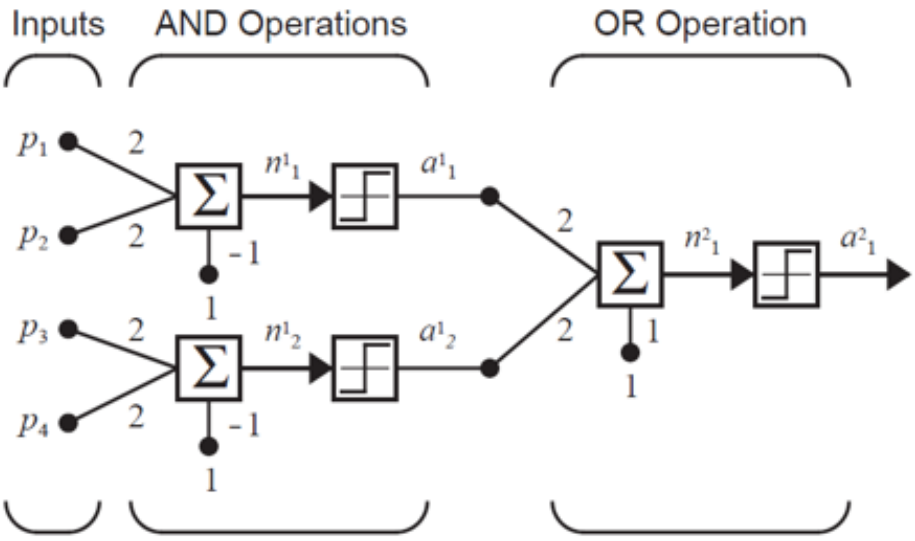
Problem 1: Statement (Understanding inputs)

- Consider the patterns and their classes
  - Class I represents vertical lines
  - Class II represents horizontal lines



Blue corresponds to 1 and white corresponds to -1 and the reading of the graphic representation is column by column.

The problem is modalized by the following Neural Network:



1) What are the value of the input vectors?

$$p_a = \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \end{bmatrix} \quad p_b = \begin{bmatrix} -1 \\ -1 \\ 1 \\ 1 \end{bmatrix} \quad p_c = \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \end{bmatrix} \quad p_d = \begin{bmatrix} -1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$$

2) What is the corresponding W ?

$$W^1 = \begin{bmatrix} 2 & 2 & 0 & 0 \\ 0 & 0 & 2 & 2 \end{bmatrix}$$

$$W^2 = \begin{bmatrix} 2 & 2 \end{bmatrix}$$

3) What is the corresponding a^2_1 to the corresponding inputs pa, pb, pc, pd.

for p_a

$a^1 = \text{hardlims}(W^1 p + b^1) = \text{hardlims}\left(\begin{bmatrix} 2 & 2 & 0 & 0 \\ 0 & 0 & 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \end{bmatrix} + \begin{bmatrix} -1 \\ -1 \end{bmatrix}\right)$

$2(1) + 2(1) + 0(-1) + 0(-1) = 4 - 1 = 3$

$0(1) + 0(1) + 2(-1) + 2(-1) = -4 - 1 = -5$

$a^1 = \text{hardlims}\left(\begin{bmatrix} 3 \\ -5 \end{bmatrix}\right) = \begin{bmatrix} 1 \\ -1 \end{bmatrix} = \boxed{a^1}$

$a^2 = \text{hardlims}(W^2 a^1 + b^2) = \text{hardlims}\left(\begin{bmatrix} 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ -1 \end{bmatrix} + \begin{bmatrix} 1 \end{bmatrix}\right) = 2 - 2 + 1 = \text{hardlims}(1) = 1$

for p_b

$a^1 = \text{hardlims}(W^1 p + b^1) = \text{hardlims}\left(\begin{bmatrix} 2 & 2 & 0 & 0 \\ 0 & 0 & 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} -1 \\ -1 \\ 1 \\ 1 \end{bmatrix} + \begin{bmatrix} -1 \\ -1 \end{bmatrix}\right)$

$2(-1) + 2(-1) + 0(1) + 0(1) = -4 - 1 = -5$

$0(-1) + 0(-1) + 2(1) + 2(1) = 4 - 1 = 3$

$a^1 = \text{hardlims}\left(\begin{bmatrix} -5 \\ 3 \end{bmatrix}\right) = \begin{bmatrix} -1 \\ 1 \end{bmatrix} = \boxed{a^1}$

$a^2 = \text{hardlims}(W^2 a^1 + b^2) = \text{hardlims}\left(\begin{bmatrix} 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} -1 \\ 1 \end{bmatrix} + \begin{bmatrix} 1 \end{bmatrix}\right) = -2 + 2 + 1 = \text{hardlims}(1) = 1$

for p_c

$a^1 = \text{hardlims}(W^1 p + b^1) = \text{hardlims}\left(\begin{bmatrix} 2 & 2 & 0 & 0 \\ 0 & 0 & 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \end{bmatrix} + \begin{bmatrix} -1 \\ -1 \end{bmatrix}\right)$

$2(1) + 2(-1) + 0(1) + 0(-1) = 2 - 2 - 1 = -1$

$0(1) + 0(-1) + 2(1) + 2(-1) = 2 - 2 - 1 = -1$

$a^1 = \text{hardlims}\left(\begin{bmatrix} -1 \\ -1 \end{bmatrix}\right) = \begin{bmatrix} -1 \\ -1 \end{bmatrix} = \boxed{a^1}$

$a^2 = \text{hardlims}(W^2 a^1 + b^2) = \text{hardlims}\left(\begin{bmatrix} 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} -1 \\ -1 \end{bmatrix} + \begin{bmatrix} 1 \end{bmatrix}\right) = -2 - 2 + 1 = -3 \Rightarrow \text{hardlims}(-3) = -1 = \boxed{a^2}$

for p_d

$a^1 = \text{hardlims}(W^1 p + b^1) = \text{hardlims}\left(\begin{bmatrix} 2 & 2 & 0 & 0 \\ 0 & 0 & 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} -1 \\ 1 \\ -1 \\ 1 \end{bmatrix} + \begin{bmatrix} -1 \\ -1 \end{bmatrix}\right)$

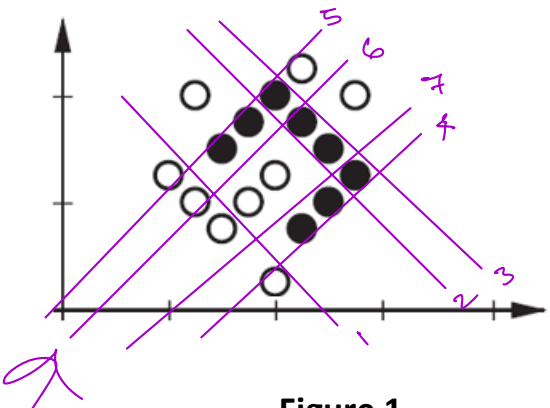
$2(-1) + 2(1) + 0(-1) + 0(1) = -2 + 2 - 1 = -1$

$0(-1) + 0(1) + 2(-1) + 2(1) = -2 + 2 - 1 = -1$ $\Rightarrow$ $\text{hardlims}\left(\begin{bmatrix} -1 \\ -1 \end{bmatrix}\right) = \begin{bmatrix} -1 \\ -1 \end{bmatrix} = \boxed{a^1}$

$a^2 = \text{hardlims}(W^2 a^1 + b^2) = \text{hardlims}\left(\begin{bmatrix} 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} -1 \\ -1 \end{bmatrix} + \begin{bmatrix} 1 \end{bmatrix}\right) = -2 - 2 + 1 = -3 \Rightarrow \text{hardlims}(-3) = -1 = \boxed{a^2}$

p_a $a^2 = 1$, p_b $a^2 = 1$, p_c $a^2 = -1$, p_d $a^2 = -1$

Problem 2: multi-layer Neural Network



7 Decision boundaries drawn

Figure 1

- White circles represent Class I
- Black circles represent Class II

4) What kind of Neural network will be used to classify the set of circles? Why?

Multilayer Neural Network because 2 classes can't be separated with single line

5) Draw decision boundaries of the two classes of figure 1. For each decision boundary calculate the corresponding decision vector and deduce the corresponding orthogonal weight.

DB 1 $A = [2 \ 0.5]$ $B = [1 \ 1.5]$

$DV = BA = [1 \ -1]$

$\Rightarrow W^T = [1 \ 1]$

"orthogonal" $W = BA \cdot W = 0$

$= [1(1) + (-1)(1)] = 0$

$W = [1 \ 1]$

DB 2 $A = [3 \ 0.7]$ $B = [2 \ 1.7]$

$DV = BA = [1 \ -1]$ $W^T = [1 \ 1]$

$W = BA \cdot W = 0$

$= [1(1) + 1(-1)] = 0$

$W = [1 \ 1]$

DB 3 $A = [3 \ 1.2]$ $B = [2 \ 2.2]$

$DV = BA = [-1 \ 1]$

$W^T = [-1 \ -1]$

$W = B \cdot W = 0$

$= [-1(-1) + 1(-1)] = 0$

$W = [-1 \ -1]$

DB 4 $A = [3 \ 1.2]$ $B = [2 \ 0.2]$

$DV = BA = [1 \ 1]$ $W^T = [-1 \ 1]$

$W = BA \cdot W = 0$

$W = [-1(1) + 1(1)] = 0$

$W = [-1 \ 1]$

DB 5 $A = [2 \quad 2.1]$ $B = [1 \quad 1.1]$

$DV = BA = [1 \quad 1]$ $W^T = [1 \quad -1]$

$OW = BA \cdot W = 0$

$OW = [(1) + 1(-1)] = 0$

$OW = [1 \quad -1]$

DB 6 $A = [2 \quad 1.6]$ $B = [1 \quad 0.6]$ $W^T = [-1 \quad 1]$

$DV = BA = [1 \quad 1]$ $OW = BA \cdot W = 0$

$OW = [-1(1) + 1(1)] = 0$

$OW = [-1 \quad 1]$

DB 7 $A = [3 \quad 1.8]$ $B = [2 \quad 0.8]$ $W^T = [1 \quad -1]$

$DV = BA = [1 \quad 1]$ $OW = BA \cdot W = 0$

$OW = [1(1) + 1(-1)] = 0$

$OW = [1 \quad -1]$

6) Deduce the weight matrix for the whole system

$$W_1 = \begin{bmatrix} 1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & 1 & -1 & 1 & -1 \end{bmatrix}$$

7) Deduce the associated bias

$P_1 = \begin{bmatrix} 1.5 \\ 1.2 \end{bmatrix}$ $b_1 = -W_1^T P_1 = -([1 \quad 1] \cdot \begin{bmatrix} 1.5 \\ 1.2 \end{bmatrix}) = -(1.5 + 1.2) = -2.7$

$P_2 = \begin{bmatrix} 2.5 \\ 1.3 \end{bmatrix}$ $b_2 = -W_1^T P_2 = -([1 \quad 1] \cdot \begin{bmatrix} 2.5 \\ 1.3 \end{bmatrix}) = -(2.5 + 1.3) = -3.8$

$P_3 = \begin{bmatrix} 3.5 \\ 1.8 \end{bmatrix}$ $b_3 = -W_1^T P_3 = -([-1 \quad -1] \cdot \begin{bmatrix} 3.5 \\ 1.8 \end{bmatrix}) = -(-3.5 - 1.8) = 5.3$

$P_4 = \begin{bmatrix} 2.5 \\ 1.6 \end{bmatrix}$ $b_4 = -W_1^T P_4 = -([-1 \quad 1] \cdot \begin{bmatrix} 2.5 \\ 1.6 \end{bmatrix}) = -(-2.5 + 1.6) = 0.9$

$P_5 = \begin{bmatrix} 1 \\ 1.1 \end{bmatrix}$ $b_5 = -W_1^T P_5 = -([1 \quad -1] \cdot \begin{bmatrix} 1 \\ 1.1 \end{bmatrix}) = -(1 - 1.1) = 0.1$

$P_6 = \begin{bmatrix} 1.5 \\ 1.1 \end{bmatrix}$ $b_6 = -W_1^T P_6 = -([-1 \quad 1] \cdot \begin{bmatrix} 1.5 \\ 1.1 \end{bmatrix}) = -(-1.5 + 1.1) = 0.4$

$P_7 = \begin{bmatrix} 2.6 \\ 1.3 \end{bmatrix}$ $b_7 = -W_1^T P_7 = -([1 \quad -1] \cdot \begin{bmatrix} 2.6 \\ 1.3 \end{bmatrix}) = -(2.6 - 1.3) = -1.3$

$b_1 = [-2.7 \quad -3.8 \quad 5.3 \quad 0.9 \quad 0.1 \quad 0.4 \quad -1.3]$

8) Deduce the W^2 based on AND GATE.

$S = 3$ $R = 7$

Neuron 1 ⇒ 5 and 6 and 3 and 1 are 1 output 1

Neuron 2 ⇒ 5 and 4 and 3 and 2 are 1 output 1

Neuron 3 ⇒ 7 and 4 and 3 and 1 are 1 output 1

$$W_2 = \begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$$