

EXPERIMENT-1

SANJAY DHAKAR

(24UADS1046)

Objective :- WAP to visualize the Perceptron Learning Algorithm using numpy and matplotlib/seaborn in Python. Evaluate performance of a single perceptron for NAND and XOR truth tables as input dataset.

Source Code :-

```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns

sns.set(style="whitegrid")

class Perceptron:
    def __init__(self, lr=0.1, epochs=20):
        self.lr = lr
        self.epochs = epochs

    def step(self, z):
        return np.where(z >= 0, 1, 0)

    def predict(self, X):
        z = np.dot(X, self.w) + self.b
        return self.step(z)

    def fit(self, X, y):
        self.w = np.zeros(X.shape[1])
        self.b = 0

        self.weight_history = []
        self.loss_history = []
        self.acc_history = []

        for epoch in range(self.epochs):
            total_error = 0
```

```

print(f"\nEpoch {epoch+1}")

for i in range(len(X)):
    z = np.dot(X[i], self.w) + self.b
    y_pred = self.step(z)

    error = y[i] - y_pred
    total_error += abs(error)

    self.w += self.lr * error * X[i]
    self.b += self.lr * error

    print(f"Sample {i+1} | w={self.w} | b={self.b}")

self.loss_history.append(total_error)

# Accuracy per epoch
y_epoch_pred = self.predict(X)
acc = np.mean(y_epoch_pred == y)
self.acc_history.append(acc)

print(f"Loss={total_error}, Accuracy={acc*100:.2f}%")

if total_error == 0:
    print("✅ Converged!")
    break

def plot_decision_boundary(X, y, w, b, title):
    plt.figure(figsize=(5,5))
    sns.scatterplot(x=X[:,0], y=X[:,1], hue=y, s=100)

    x_vals = np.array([0, 1])
    y_vals = -(w[0]*x_vals + b) / w[1]
    plt.plot(x_vals, y_vals, 'k--')

    plt.title(title)
    plt.xlabel("x1")
    plt.ylabel("x2")
    plt.show()

```

```

def plot_loss(loss, title):
    plt.figure(figsize=(5,3))
    plt.plot(loss, marker='o')
    plt.title(title)
    plt.xlabel("Epoch")
    plt.ylabel("Total Misclassifications")
    plt.show()

def plot_accuracy(acc, title):
    plt.figure(figsize=(5,3))
    plt.plot(acc, marker='o')
    plt.ylim(0, 1.05)
    plt.xlabel("Epoch")
    plt.ylabel("Accuracy")
    plt.title(title)
    plt.show()

X_nand = np.array([
    [0,0],
    [0,1],
    [1,0],
    [1,1]
])

y_nand = np.array([1,1,1,0])

p_nand = Perceptron(lr=0.1, epochs=10)
p_nand.fit(X_nand, y_nand)

plot_loss(p_nand.loss_history, "NAND - Training Error")
plot_decision_boundary(X_nand, y_nand, p_nand.w, p_nand.b, "NAND - Final Decision Boundary")

y_pred_nand = p_nand.predict(X_nand)
nand_acc = np.mean(y_pred_nand == y_nand)

print("Final NAND Accuracy:", nand_acc)

plot_accuracy(p_nand.acc_history, "NAND Accuracy vs Epoch")

```

```

x_xor = np.array([
    [0,0],
    [0,1],
    [1,0],
    [1,1]
])

y_xor = np.array([0,1,1,0])

p_xor = Perceptron(lr=0.1, epochs=10)
p_xor.fit(X_xor, y_xor)

plot_loss(p_xor.loss_history, "XOR - Training Error")
plot_decision_boundary(X_xor, y_xor, p_xor.w, p_xor.b, "XOR - Final Decision Boundary")

y_pred_xor = p_xor.predict(X_xor)
xor_acc = np.mean(y_pred_xor == y_xor)

print("Final XOR Accuracy:", xor_acc)

plot_accuracy(p_xor.acc_history, "XOR Accuracy vs Epoch")

```

Output:- For NAND

Epoch 1

Sample 1 | w=[0. 0.] | b=0.0
 Sample 2 | w=[0. 0.] | b=0.0
 Sample 3 | w=[0. 0.] | b=0.0
 Sample 4 | w=[-0.1 -0.1] | b=-0.1
 Loss=1, Accuracy=25.00%

Epoch 2

Sample 1 | w=[-0.1 -0.1] | b=0.0
 Sample 2 | w=[-0.1 0.] | b=0.1
 Sample 3 | w=[-0.1 0.] | b=0.1
 Sample 4 | w=[-0.2 -0.1] | b=0.0
 Loss=3, Accuracy=50.00%

Epoch 3

Sample 1 | w=[-0.2 -0.1] | b=0.0

Sample 2 | $w=[-0.2 \ 0.]$ | $b=0.1$

Sample 3 | $w=[-0.1 \ 0.]$ | $b=0.2$

Sample 4 | $w=[-0.2 \ -0.1]$ | $b=0.1$

Loss=3, Accuracy=75.00%

Epoch 4

Sample 1 | $w=[-0.2 \ -0.1]$ | $b=0.1$

Sample 2 | $w=[-0.2 \ -0.1]$ | $b=0.1$

Sample 3 | $w=[-0.1 \ -0.1]$ | $b=0.2$

Sample 4 | $w=[-0.2 \ -0.2]$ | $b=0.1$

Loss=2, Accuracy=50.00%

Epoch 5

Sample 1 | $w=[-0.2 \ -0.2]$ | $b=0.1$

Sample 2 | $w=[-0.2 \ -0.1]$ | $b=0.2$

Sample 3 | $w=[-0.2 \ -0.1]$ | $b=0.2$

Sample 4 | $w=[-0.2 \ -0.1]$ | $b=0.2$

Loss=1, Accuracy=100.00%

Epoch 6

Sample 1 | $w=[-0.2 \ -0.1]$ | $b=0.2$

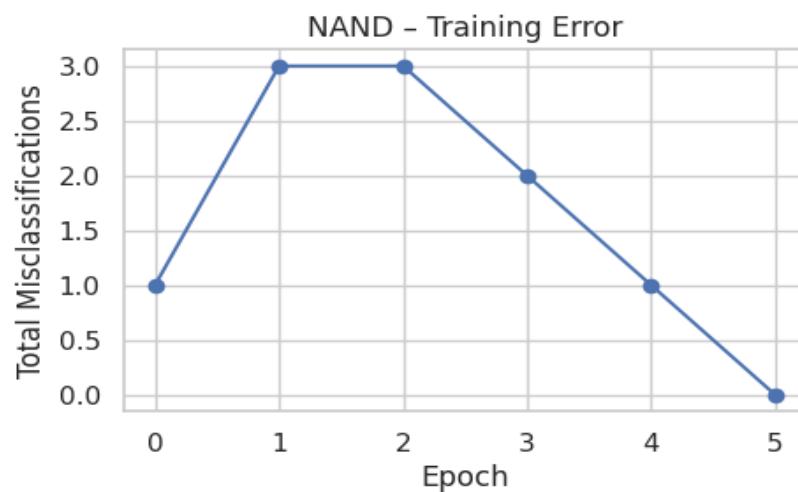
Sample 2 | $w=[-0.2 \ -0.1]$ | $b=0.2$

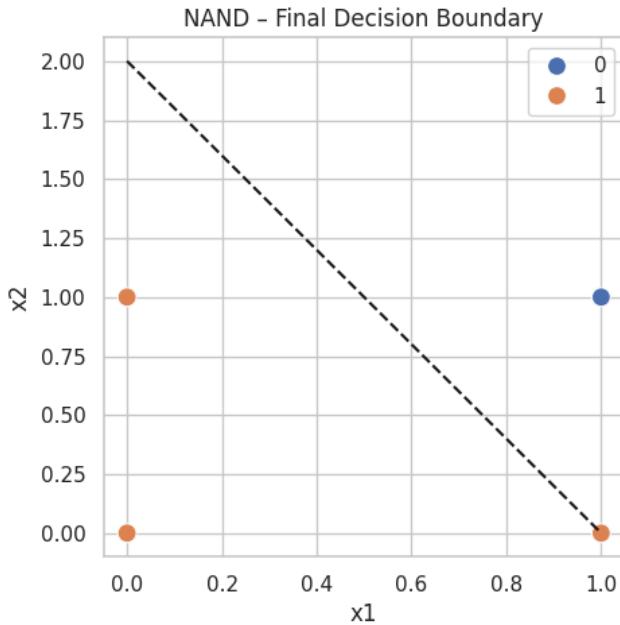
Sample 3 | $w=[-0.2 \ -0.1]$ | $b=0.2$

Sample 4 | $w=[-0.2 \ -0.1]$ | $b=0.2$

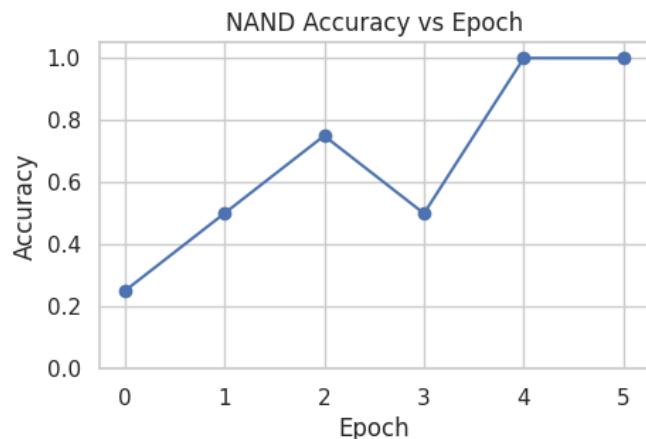
Loss=0, Accuracy=100.00%

 Converged!





Final NAND Accuracy: 1.0



FOR XOR :

Epoch 1

Sample 1 | $w=[0. 0.]$ | $b=-0.1$

Sample 2 | $w=[0. 0.1]$ | $b=0.0$

Sample 3 | $w=[0. 0.1]$ | $b=0.0$

Sample 4 | $w=[-0.1 0.]$ | $b=-0.1$

Loss=3, Accuracy=50.00%

Epoch 2

Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=3, Accuracy=50.00%

Epoch 3

Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

Epoch 4

Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

Epoch 5

Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

Epoch 6

Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

Epoch 7

Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

Epoch 8

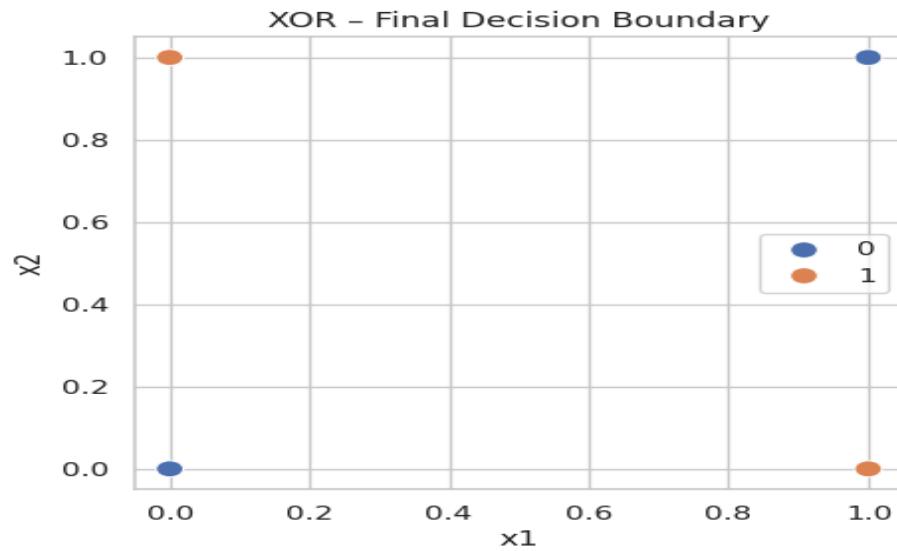
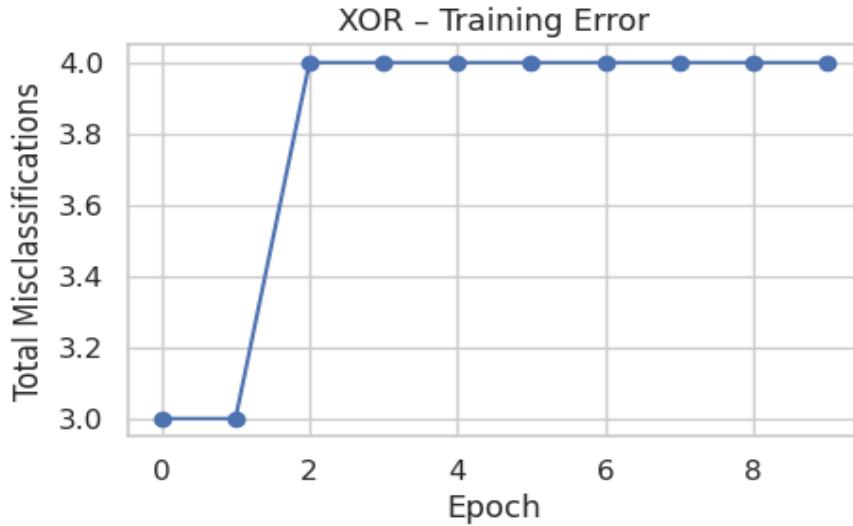
Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

Epoch 9

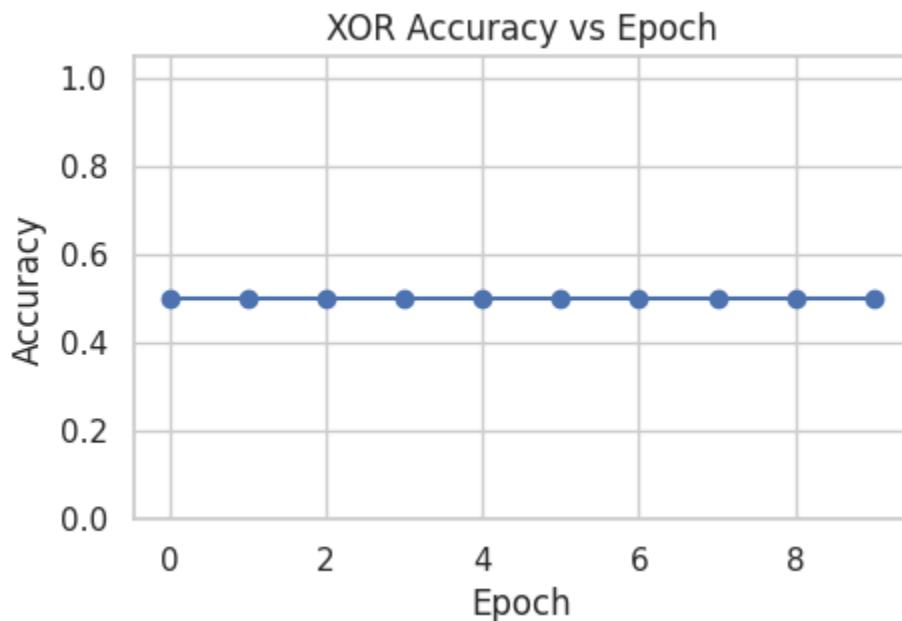
Sample 1 | w=[-0.1 0.] | b=-0.1

Sample 2 | $w=[-0.1 \ 0.1]$ | $b=0.0$
Sample 3 | $w=[0. \ 0.1]$ | $b=0.1$
Sample 4 | $w=[-0.1 \ 0.]$ | $b=0.0$
Loss=4, Accuracy=50.00%

Epoch 10
Sample 1 | $w=[-0.1 \ 0.]$ | $b=-0.1$
Sample 2 | $w=[-0.1 \ 0.1]$ | $b=0.0$
Sample 3 | $w=[0. \ 0.1]$ | $b=0.1$
Sample 4 | $w=[-0.1 \ 0.]$ | $b=0.0$
Loss=4, Accuracy=50.00%



Final XOR Accuracy: 0.5



MY COMMENTS :-

From this experiment about training and learning algorithm of single layer perceptron, i understood the concept of weights and biases and how they modified at each step to improve the results . I also understand the concept of convergence .

The Key learning from this experiment i have are :

1. The learning algorithm convergence for the NAND Gate which shows that it is linearly separable.
2. The Learning algorithm fails to convergence for XOR gate logic which shows it is not linearly separable and accuracy remained constant at 50 %