EXPERIMENT-1
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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

Description :-.

- The Perceptron Learning Algorithm is a supervised binary classification algorithm.
- It computes a weighted sum of inputs and applies a step activation function.
- Weights and bias are updated only when a sample is misclassified.
- Performance is evaluated using loss and accuracy per epoch.
- The perceptron converges for NAND (linearly separable) with 100% accuracy.
- The perceptron fails for XOR (not linearly separable), showing its limitation.

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%

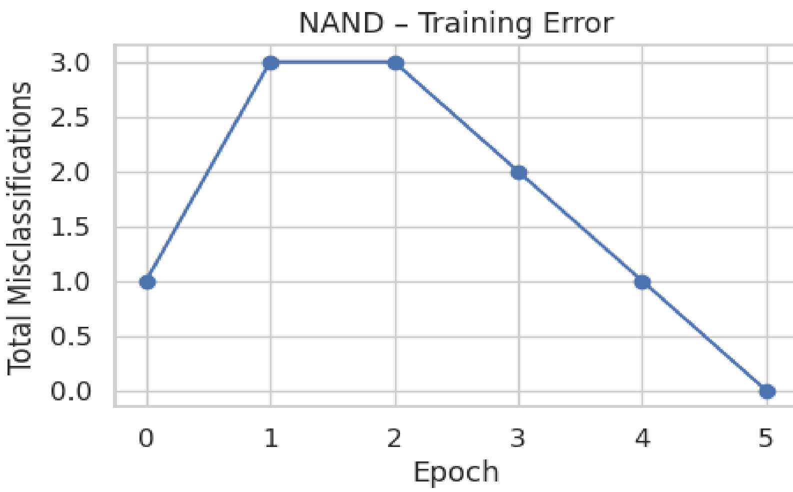
Epoch 3
Sample 1 | w=[-0.2 -0.1] | b=0.0
Sample 2 | w=[-0.2 0.] | b=0.1
Sample 3 | w=[-0.1 0.] | b=0.2
Sample 4 | w=[-0.2 -0.1] | b=0.1
Loss=3, Accuracy=75.00%

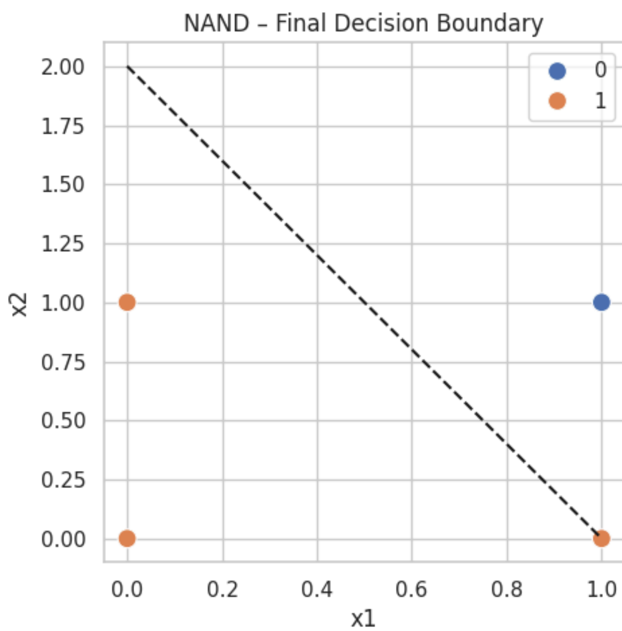
Epoch 4
Sample 1 | w=[-0.2 -0.1] | b=0.1
Sample 2 | w=[-0.2 -0.1] | b=0.1
Sample 3 | w=[-0.1 -0.1] | b=0.2
Sample 4 | w=[-0.2 -0.2] | b=0.1
Loss=2, Accuracy=50.00%

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%

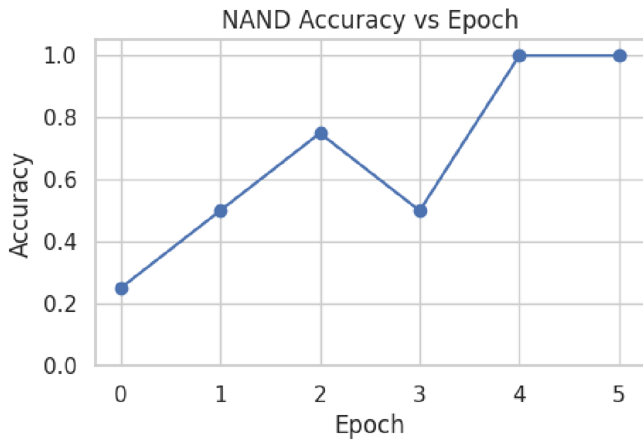
Epoch 6
Sample 1 | w=[-0.2 -0.1] | b=0.2
Sample 2 | w=[-0.2 -0.1] | b=0.2
Sample 3 | w=[-0.2 -0.1] | b=0.2
Sample 4 | w=[-0.2 -0.1] | b=0.2
Loss=0, Accuracy=100.00%

✅ 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%

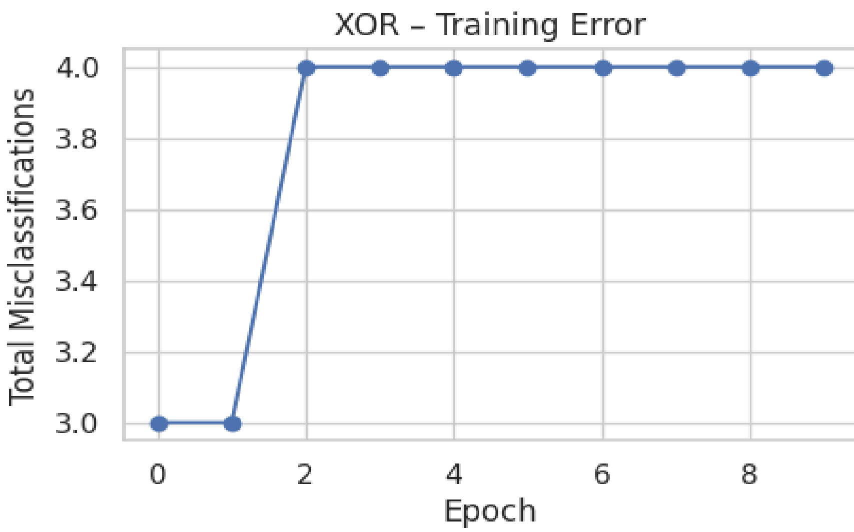
Epoch 6
Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

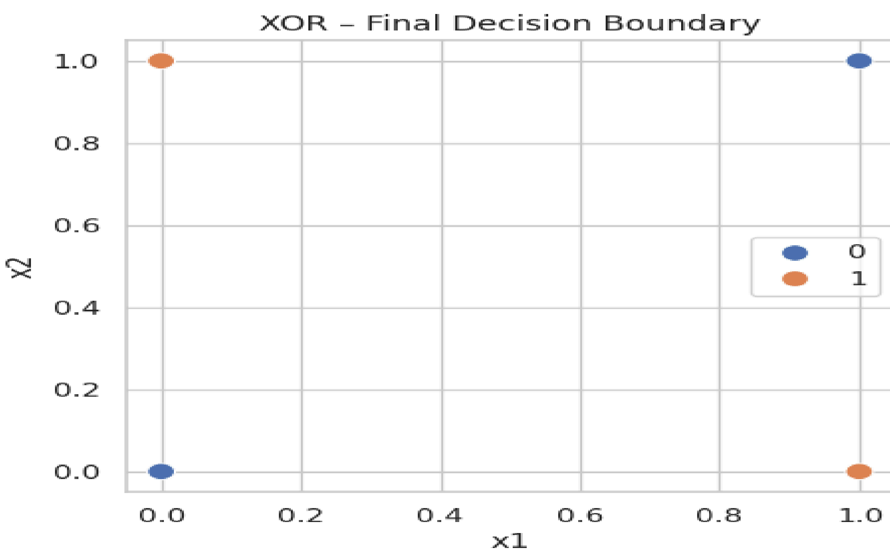
Epoch 7
Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

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%

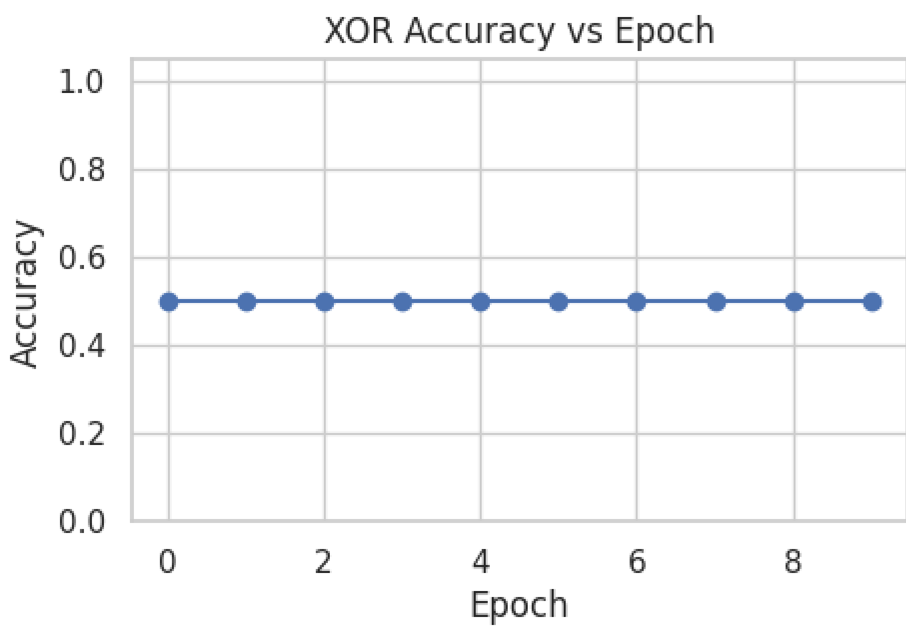
Epoch 9
Sample 1 | w=[-0.1 0.] | b=-0.1
Sample 2 | w=[-0.1 0.1] | b=0.0
Sample 3 | w=[0. 0.1] | b=0.1
Sample 4 | w=[-0.1 0.] | b=0.0
Loss=4, Accuracy=50.00%

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 %**