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Roll no: 50
Class: TY-IT A B3

R Class Single Layer Perceptron Code:

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

def signum(x):
    return 1 if x >= 0 else -1

T = np.array([[0.1, 0.1, -1, 0],
              [0.2, 0.1, -1, 0],
              [0.5, 0.1, -1, 1],
              [0.6, 0.1, -1, 1],
              [0.3, 0.3, -1, 2],
              [0.4, 0.3, -1, 2]])

W = np.array([[-0.1, 0.15, 0.2],
              [-0.2, 0.11, 0.17],
              [0.17, 0.16, 0.11]])

D = np.array([[1, -1, -1],
              [-1, 1, -1],
              [-1, -1, 1]])

learning_rate = 1
epochs = 100  # Number of epochs

c = 0  # Counter for training cycles
P = 6  # Number of training pairs
error_list = []  # List to store errors for each cycle

for epoch in range(epochs):
    c += 1
    E = 0  # Error for the current training cycle

    for p in range(P):
        x1, x2, bias, d = T[p]

        y = np.zeros(3)
        o = np.zeros(3)
```

```
        for i in range(3):
            y[i] = x1 * W[i][0] + x2 * W[i][1] + bias * W[i][2]
            o[i] = signum(y[i])

        d = int(d)  # Convert d to an integer

        for i in range(3):
            if o[i] != D[d][i]:
                for j in range(3):
                    W[i][j] += 0.5 * learning_rate * (D[d][i] - o[i]) * T[p][j]
                E += 0.5 * (D[d][i] - o[i]) ** 2

        print(f"Updated Weight Matrix (W) after X{p + 1} = [{x1:.3f}, {x2:.3f}]:")
        print(W)
        print(f"Error after processing X{p + 1} = [{x1:.3f}, {x2:.3f}]: {E:.3f}\n")

    error_list.append(E)

    if E == 0:
        print(f"Training completed in epoch {epoch + 1}/{epochs}.")
        break

# Plotting the error graph
plt.plot(range(1, c + 1), error_list, marker='o')
plt.xlabel('Cycle')
plt.ylabel('Error')
plt.title('Error vs. Cycle')
plt.grid(True)
plt.show()
```

Output:

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[0. 0.25 -0.8]
 [-0.2 0.11 0.17]
 [0.17 0.16 0.11]]
Error after processing X1 = [0.100, 0.100]: 2.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[0. 0.25 -0.8]
 [-0.2 0.11 0.17]
 [0.17 0.16 0.11]]
Error after processing X2 = [0.200, 0.100]: 2.000

Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-0.5   0.15 0.2]
 [0.3   0.21 -0.83]
 [0.17 0.16 0.11]]
Error after processing X3 = [0.500, 0.100]: 6.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-0.5   0.15 0.2]
 [0.3   0.21 -0.83]
 [-0.43 0.06 1.11]]
Error after processing X4 = [0.600, 0.100]: 8.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-0.5   0.15 0.2]
 [0.   -0.09 0.17]
 [-0.13 0.36 0.11]]
Error after processing X5 = [0.300, 0.300]: 12.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-0.5   0.15 0.2]
 [0.   -0.09 0.17]
 [0.27 0.66 -0.89]]
Error after processing X6 = [0.400, 0.300]: 14.000

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[-0.4   0.25 -0.8]
 [0.   -0.09 0.17]
 [0.17 0.56 0.11]]
Error after processing X1 = [0.100, 0.100]: 4.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[-0.4   0.25 -0.8]
 [0.   -0.09 0.17]
 [0.17 0.56 0.11]]
Error after processing X2 = [0.200, 0.100]: 4.000

Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-0.9   0.15 0.2]
 [0.5   0.01 -0.83]
 [-0.33 0.46 1.11]]
Error after processing X3 = [0.500, 0.100]: 10.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-0.9   0.15 0.2]
 [0.5   0.01 -0.83]
 [-0.33 0.46 1.11]]

Error after processing X4 = [0.600, 0.100]: 10.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-0.9   0.15 0.2]
 [0.2 -0.29 0.17]
 [-0.03 0.76 0.11]]
Error after processing X5 = [0.300, 0.300]: 14.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-0.9   0.15 0.2]
 [0.2 -0.29 0.17]
 [-0.03 0.76 0.11]]
Error after processing X6 = [0.400, 0.300]: 14.000

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[-0.8   0.25 -0.8]
 [0.2 -0.29 0.17]
 [-0.03 0.76 0.11]]
Error after processing X1 = [0.100, 0.100]: 2.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[-0.8   0.25 -0.8]
 [0.2 -0.29 0.17]
 [-0.03 0.76 0.11]]
Error after processing X2 = [0.200, 0.100]: 2.000

Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-1.3   0.15 0.2]
 [0.7 -0.19 -0.83]
 [-0.03 0.76 0.11]]
Error after processing X3 = [0.500, 0.100]: 6.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-1.3   0.15 0.2]
 [0.7 -0.19 -0.83]
 [-0.03 0.76 0.11]]
Error after processing X4 = [0.600, 0.100]: 6.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-1.3   0.15 0.2]
 [0.4 -0.49 0.17]
 [-0.03 0.76 0.11]]
Error after processing X5 = [0.300, 0.300]: 8.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-1.3   0.15 0.2]

[0.4 -0.49 0.17]
[-0.03 0.76 0.11]]
Error after processing X6 = [0.400, 0.300]: 8.000

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[-1.2   0.25 -0.8]
[0.4 -0.49 0.17]
[-0.03 0.76 0.11]]
Error after processing X1 = [0.100, 0.100]: 2.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[-1.2   0.25 -0.8]
[0.4 -0.49 0.17]
[-0.03 0.76 0.11]]
Error after processing X2 = [0.200, 0.100]: 2.000

Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-1.7   0.15 0.2]
[0.9 -0.39 -0.83]
[-0.03 0.76 0.11]]
Error after processing X3 = [0.500, 0.100]: 6.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-1.7   0.15 0.2]
[0.9 -0.39 -0.83]
[-0.03 0.76 0.11]]
Error after processing X4 = [0.600, 0.100]: 6.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-1.7   0.15 0.2]
[0.6 -0.69 0.17]
[-0.03 0.76 0.11]]
Error after processing X5 = [0.300, 0.300]: 8.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-1.7   0.15 0.2]
[0.6 -0.69 0.17]
[-0.03 0.76 0.11]]
Error after processing X6 = [0.400, 0.300]: 8.000

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[-1.6   0.25 -0.8]
[0.6 -0.69 0.17]
[-0.03 0.76 0.11]]
Error after processing X1 = [0.100, 0.100]: 2.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[-1.6 0.25 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X2 = [0.200, 0.100]: 2.000

Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-2.1 0.15 0.2]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X3 = [0.500, 0.100]: 4.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-2.1 0.15 0.2]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X4 = [0.600, 0.100]: 4.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-2.1 0.15 0.2]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X5 = [0.300, 0.300]: 4.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-2.1 0.15 0.2]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X6 = [0.400, 0.300]: 4.000

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[-2. 0.25 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X1 = [0.100, 0.100]: 2.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[-2. 0.25 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X2 = [0.200, 0.100]: 2.000

Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-2. 0.25 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]

Error after processing X3 = [0.500, 0.100]: 2.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-2. 0.25 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X4 = [0.600, 0.100]: 2.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-2.3 -0.05 0.2]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X5 = [0.300, 0.300]: 4.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-2.3 -0.05 0.2]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X6 = [0.400, 0.300]: 4.000

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[-2.2   0.05 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X1 = [0.100, 0.100]: 2.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[-2.2   0.05 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X2 = [0.200, 0.100]: 2.000

Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-2.2   0.05 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X3 = [0.500, 0.100]: 2.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-2.2   0.05 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X4 = [0.600, 0.100]: 2.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-2.5 -0.25 0.2]

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 [ 0.6  -0.69  0.17]
 [-0.03  0.76  0.11]]
Error after processing X5 = [0.300, 0.300]: 4.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-2.5  -0.25  0.2 ]
 [ 0.6  -0.69  0.17]
 [-0.03  0.76  0.11]]
Error after processing X6 = [0.400, 0.300]: 4.000

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[-2.4  -0.15 -0.8 ]
 [ 0.6  -0.69  0.17]
 [-0.03  0.76  0.11]]
Error after processing X1 = [0.100, 0.100]: 2.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[-2.4  -0.15 -0.8 ]
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Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-2.4  -0.15 -0.8 ]
 [ 0.6  -0.69  0.17]
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Error after processing X3 = [0.500, 0.100]: 2.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-2.4  -0.15 -0.8 ]
 [ 0.6  -0.69  0.17]
 [-0.03  0.76  0.11]]
Error after processing X4 = [0.600, 0.100]: 2.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-2.7  -0.45  0.2 ]
 [ 0.6  -0.69  0.17]
 [-0.03  0.76  0.11]]
Error after processing X5 = [0.300, 0.300]: 4.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-2.7  -0.45  0.2 ]
 [ 0.6  -0.69  0.17]
 [-0.03  0.76  0.11]]
Error after processing X6 = [0.400, 0.300]: 4.000
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Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X1 = [0.100, 0.100]: 2.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
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Error after processing X2 = [0.200, 0.100]: 2.000

Updated Weight Matrix (W) after X3 = [0.500, 0.100]:
[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X3 = [0.500, 0.100]: 2.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X4 = [0.600, 0.100]: 2.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X5 = [0.300, 0.300]: 2.000

Updated Weight Matrix (W) after X6 = [0.400, 0.300]:
[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X6 = [0.400, 0.300]: 2.000

Updated Weight Matrix (W) after X1 = [0.100, 0.100]:
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 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X1 = [0.100, 0.100]: 0.000

Updated Weight Matrix (W) after X2 = [0.200, 0.100]:
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 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]

Error after processing X2 = [0.200, 0.100]: 0.000

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[[-2.6 -0.35 -0.8]
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Error after processing X3 = [0.500, 0.100]: 0.000

Updated Weight Matrix (W) after X4 = [0.600, 0.100]:
[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X4 = [0.600, 0.100]: 0.000

Updated Weight Matrix (W) after X5 = [0.300, 0.300]:
[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X5 = [0.300, 0.300]: 0.000

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[[-2.6 -0.35 -0.8]
 [0.6 -0.69 0.17]
 [-0.03 0.76 0.11]]
Error after processing X6 = [0.400, 0.300]: 0.000

Training completed in epoch 10/100.