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Implementation of MCP Neuron for AND and OR Function.

[1]
```
def MCP_Neurons_AND(X1, X2, T):
    """
    This functions implements basic AND operations with MCP Neuron for two inputs.
    Arguments:
    Inputs:
    X1 (1 nd array): An array of binary values.
    X2 (1 nd array): An array of binary values.
    Output:
    state_neuron(1D-list): An state of neuron 1 0r 0 for the particular inputs.
    """
    assert len(X1) == len(X2)
    ### YOUR CODE HERE ###
    # Perform an element wise addition of two input arrays stored in a new array(list):
    new_array = []
    for x1,x2 in zip(X1,X2):
        new_array.append(x1+x2)
    # Create a new array to put all the prediction let's name that a state_neuron.
    state_neuron = []
    # Append 1 in sate_neuron if sum (element) of above list is above Threshold else append 0.
    for i in range(len(new_array)):
        if new_array[i] >= T:
            state_neuron.append(1)
        else:
            state_neuron.append(0)
    return state_neuron
```

```
# Example usage for MCP_Neurons_AND function
X1 = [0, 0, 1, 1]
X2 = [0, 1, 0, 1]
T = 2  # Threshold value

# Call the MCP_Neurons_AND function
result = MCP_Neurons_AND(X1, X2, T)

# Print the result
print(f"Output of AND gate for inputs {X1} and {X2} with threshold {T}: {result}")
```

```
Output of AND gate for inputs [0, 0, 1, 1] and [0, 1, 0, 1] with threshold 2: [0, 0, 0, 1]
```

```python
def MCP_Neurons_OR(X1, X2, T):
    """
    This function implements basic OR operations with MCP Neuron for two inputs.
    Arguments:
    Inputs:
    X1 (1D array): An array of binary values.
    X2 (1D array): An array of binary values.
    Output:
    state_neuron (1D list): The state of the neuron (1 or 0) for the particular inputs.
    """
    assert len(X1) == len(X2)
    ### YOUR CODE HERE ###
    # Perform an element wise addition of two input arrays stored in a new array(list):
    new_array = []
    for x1,x2 in zip(X1,X2):
        new_array.append(x1+x2)
    # Create a new array to put all the prediction let's name that a state_neuron.
    state_neuron = []
    # Append 1 in sate_neuron if sum (element) of above list is above Threshold else append 0.
    for i in range(len(new_array)):
        if new_array[i] >= T:
            state_neuron.append(1)
        else:
            state_neuron.append(0)
    return state_neuron
```

[4]

```python
# Example usage for MCP_Neurons_OR function
X1 = [0, 0, 1, 1]
X2 = [0, 1, 0, 1]
T = 1  # Threshold value for OR gate

# Call the MCP_Neurons_OR function
result_or = MCP_Neurons_OR(X1, X2, T)

# Print the result
print(f"Output of OR gate for inputs {X1} and {X2} with threshold {T}: {result_or}")
```

```
Output of OR gate for inputs [0, 0, 1, 1] and [0, 1, 0, 1] with threshold 1: [0, 1, 1, 1]
```

Step 1: Load the Dataset

[5]
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

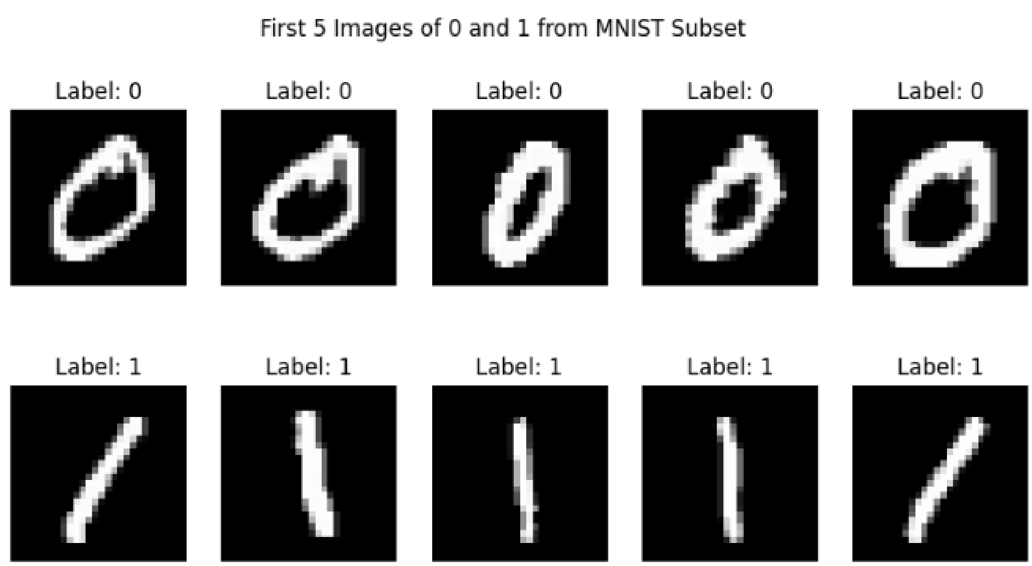
[6]
```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

[7]
```
# Load the dataset
df_0_1 = pd.read_csv("/content/drive/MyDrive/Artificial Intelligence and Machine Learning/mnist_0_and_1.csv")  # Add the correct file path if necessary

# Extract features and labels
X = df_0_1.drop(columns=["label"]).values  # 784 pixels
y = df_0_1["label"].values  # Labels (0 or 1)

# Check the shape of the features and labels
print("Feature matrix shape:", X.shape)
print("Label vector shape:", y.shape)
```

```
Feature matrix shape: (12665, 784)
Label vector shape: (12665,)
```

```
fig, axes = plt.subplots(2, 5, figsize=(10, 5))

# Check if the arrays have the required amount of data
if len(images_0) < 5 or len(images_1) < 5:
    print("Error: Not enough images in images_0 or images_1 to plot 5 images.")
else:
    for i in range(5):
        # Plot digit 0
        axes[0, i].imshow(images_0[i].reshape(28, 28), cmap="gray")
        axes[0, i].set_title("Label: 0")
        axes[0, i].axis("off")
        # Plot digit 1
        axes[1, i].imshow(images_1[i].reshape(28, 28), cmap="gray")
        axes[1, i].set_title("Label: 1")
        axes[1, i].axis("off")
    plt.suptitle("First 5 Images of 0 and 1 from MNIST Subset")
    plt.show()
```



Step - 2 - Initializing the Weights:

[9]
```
# Initialize weights and bias
weights = np.zeros(X.shape[1])  # 784 weights (one for each pixel)
bias = 0
learning_rate = 0.1
epochs = 100
```

Step - 3 - Make a Decision function:

[10]
```
import numpy as np

def decision_function(X, weights, bias):
    """
    Compute the predicted labels for the input data.

    Parameters:
    - X: Features (input data) as a numpy array of shape (n_samples, n_features)
    - weights: Updated weights after training
    - bias: Updated bias after training

    Returns:
    - y_pred_all: The predicted labels for the input data
    """
    predictions = np.dot(X, weights) + bias
    #####Your Code Here############  # Activation function (step function)
    y_pred_all = np.where(predictions>=0, 1, 0)
    return y_pred_all
```

```python
def train_perceptron(X, y, weights, bias, learning_rate=0.1, epochs=100):
    """
    Train the perceptron using the Perceptron Learning Algorithm.

    Parameters:
    - X: Features (input data) as a numpy array of shape (n_samples, n_features)
    - y: Labels (true output) as a numpy array of shape (n_samples,)
    - weights: Initial weights as a numpy array of shape (n_features,)
    - bias: Initial bias value (scalar)
    - learning_rate: Learning rate for weight updates (default is 0.1)
    - epochs: Number of iterations to train the model (default is 100)

    Returns:
    - weights: Updated weights after training
    - bias: Updated bias after training
    - accuracy: Total correct prediction.
    """
    # Step 3: Perceptron Learning Algorithm
    # Your Code here#
    n_sample = X.shape[0]
    for epoch in range(epochs):
        correct_prediction = 0
        for i in range(n_sample):
            predict = np.dot(X[i], weights) + bias
            y_pred = 1 if predict >= 0 else 0

            if y_pred == y[i]:
                correct_prediction += 1

            error = y[i] - y_pred
            weights += learning_rate * error * X[i]
            bias += learning_rate * error

        if epoch%10 == 0:
            print(f"Epoch {epoch}: Accuracy = {correct_prediction/n_sample:.4f}")

    accuracy = correct_prediction / n_sample


    return weights, bias, accuracy
```

Training the Perceptron

[12]
```
# After training the model with the perceptron_learning_algorithm
weights, bias, accuracy = train_perceptron(X, y, weights, bias)

# Evaluate the model using the new function
print("The Final Accuracy is: ", accuracy)
```

```
Epoch 0: Accuracy = 0.9967
Epoch 10: Accuracy = 0.9995
Epoch 20: Accuracy = 1.0000
Epoch 30: Accuracy = 1.0000
Epoch 40: Accuracy = 1.0000
Epoch 50: Accuracy = 1.0000
Epoch 60: Accuracy = 1.0000
Epoch 70: Accuracy = 1.0000
Epoch 80: Accuracy = 1.0000
Epoch 90: Accuracy = 1.0000
The Final Accuracy is:  1.0
```

Step 5: Visualize Misclassified Images

[13]
```
# Get predictions for all data points
predictions = np.dot(X, weights) + bias
y_pred = np.where(predictions >= 0, 1, 0)

# Calculate final accuracy
final_accuracy = np.mean(y_pred == y)
print(f"Final Accuracy: {final_accuracy:.4f}")

# Step 5: Visualize Misclassified Images
misclassified_idx = np.where(y_pred != y)[0]
if len(misclassified_idx) > 0:
    fig, axes = plt.subplots(2, 5, figsize=(10, 5))
    for ax, idx in zip(axes.flat, misclassified_idx[:10]):  # Show 10 misclassified images
        ax.imshow(X[idx].reshape(28, 28), cmap="gray")
        ax.set_title(f"Pred: {y_pred[idx]}, True: {y[idx]}")
        ax.axis("off")
    plt.suptitle("Misclassified Images")
    plt.show()
else:
    print("All images were correctly classified!")
```

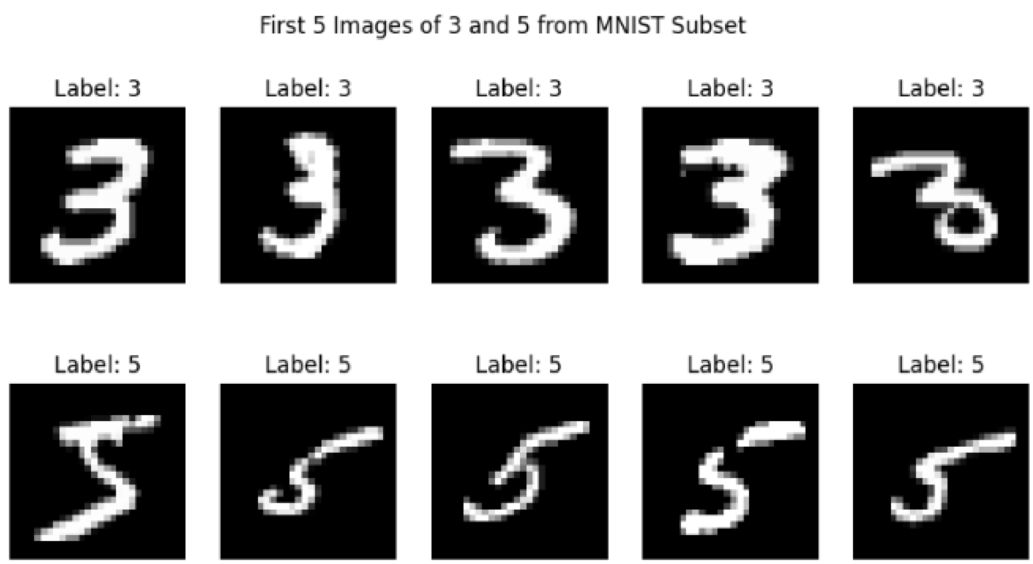
```
Final Accuracy: 1.0000
All images were correctly classified!
```

Part 2

```python
# Load the dataset
df_3_5 = pd.read_csv("/content/drive/MyDrive/Artificial Intelligence and Machine Learning/mnist_3_and_5.csv")  # Add the correct file path if necessary

# Extract features and labels
X = df_3_5.drop(columns=["label"]).values  # 784 pixels
y = df_3_5["label"].values  # Labels (3 or 5)

# Check the shape of the features and labels
print("Feature matrix shape:", X.shape)
print("Label vector shape:", y.shape)
```

```
Feature matrix shape: (2741, 784)
Label vector shape: (2741,)
```

```python
# Separate images for label 0 and label 1
images_3 = X[y == 3]  # Get all images with label 0
images_5 = X[y == 5]  # Get all images with label 1

fig, axes = plt.subplots(2, 5, figsize=(10, 5))

# Check if the arrays have the required amount of data
if len(images_3) < 5 or len(images_5) < 5:
    print("Error: Not enough images in images_3 or images_5 to plot 5 images.")
else:
    for i in range(5):
        # Plot digit 0
        axes[0, i].imshow(images_3[i].reshape(28, 28), cmap="gray")
        axes[0, i].set_title("Label: 3")
        axes[0, i].axis("off")
        # Plot digit 1
        axes[1, i].imshow(images_5[i].reshape(28, 28), cmap="gray")
        axes[1, i].set_title("Label: 5")
        axes[1, i].axis("off")
    plt.suptitle("First 5 Images of 3 and 5 from MNIST Subset")
```



```python
weights= np.zeros(X.shape[1])  # 784 weights (one for each pixel)
bias = 0
learning_rate = 0.1
epochs = 100
```

[17]
```python
def decision_function(X, weights, bias):
    """
    Compute the predicted labels for the input data.

    Parameters:
    - X: Features (input data) as a numpy array of shape (n_samples, n_features)
    - weights: Updated weights after training
    - bias: Updated bias after training

    Returns:
    - y_pred_all: The predicted labels for the input data
    """
    predictions = np.dot(X, weights) + bias
    #####Your Code Here############  # Activation function (step function)
    y_pred_all = np.where(predictions>=0, 5, 3)
    return y_pred_all
```

[18]
```python
def train_perceptron(X, y, weights, bias, learning_rate=0.1, epochs=100):
    """
    Train the perceptron using the Perceptron Learning Algorithm.

    Parameters:
    - X: Features (input data) as a numpy array of shape (n_samples, n_features)
    - y: Labels (true output) as a numpy array of shape (n_samples,)
    - weights: Initial weights as a numpy array of shape (n_features,)
    - bias: Initial bias value (scalar)
    - learning_rate: Learning rate for weight updates (default is 0.1)
    - epochs: Number of iterations to train the model (default is 100)

    Returns:
    - weights: Updated weights after training
    - bias: Updated bias after training
    - accuracy: Total correct prediction.
    """
    # Step 3: Perceptron Learning Algorithm
    # Your Code here#
    n_sample = X.shape[0]
    for epoch in range(epochs):
        correct_prediction = 0
        for i in range(n_sample):
            predict = np.dot(X[i], weights) + bias
            y_pred = 5 if predict >= 0 else 3

            if y_pred == y[i]:
                correct_prediction += 1

            error = y[i] - y_pred
            weights += learning_rate * error * X[i]
            bias += learning_rate * error

        if epoch%10 == 0:
            print(f"Epoch {epoch}: Accuracy = {correct_prediction/n_sample:.4f}")

    accuracy = correct_prediction / n_sample


    return weights, bias, accuracy
```

[19]

```python
weights, bias, accuracy = train_perceptron(X, y, weights, bias)

# Evaluate the model using the new function
print("The Final Accuracy is: ", accuracy)
```

```
Epoch 0: Accuracy = 0.9157
Epoch 10: Accuracy = 0.9599
Epoch 20: Accuracy = 0.9701
Epoch 30: Accuracy = 0.9668
Epoch 40: Accuracy = 0.9759
Epoch 50: Accuracy = 0.9763
Epoch 60: Accuracy = 0.9752
Epoch 70: Accuracy = 0.9810
Epoch 80: Accuracy = 0.9792
Epoch 90: Accuracy = 0.9825
The Final Accuracy is:  0.9857716161984678
```

```python
# Get predictions for all data points
predictions = np.dot(X, weights) + bias
y_pred = np.where(predictions >= 0, 5, 3)

# Calculate final accuracy
final_accuracy = np.mean(y_pred == y)
print(f"Final Accuracy: {final_accuracy:.4f}")

# Step 5: Visualize Misclassified Images
misclassified_idx = np.where(y_pred != y)[0]
if len(misclassified_idx) > 0:
    fig, axes = plt.subplots(2, 5, figsize=(10, 5))
    for ax, idx in zip(axes.flat, misclassified_idx[:10]):  # Show 10 misclassified images
        ax.imshow(X[idx].reshape(28, 28), cmap="gray")
        ax.set_title(f"Pred: {y_pred[idx]}, True: {y[idx]}")
        ax.axis("off")
    plt.suptitle("Misclassified Images")
    plt.show()
else:
    print("All images were correctly classified!")
```

```
Final Accuracy: 0.9869
```

```
Final Accuracy: 0.9869
```