

## LAB Assignment No. 5

### Topic: Artificial Neural Network Model

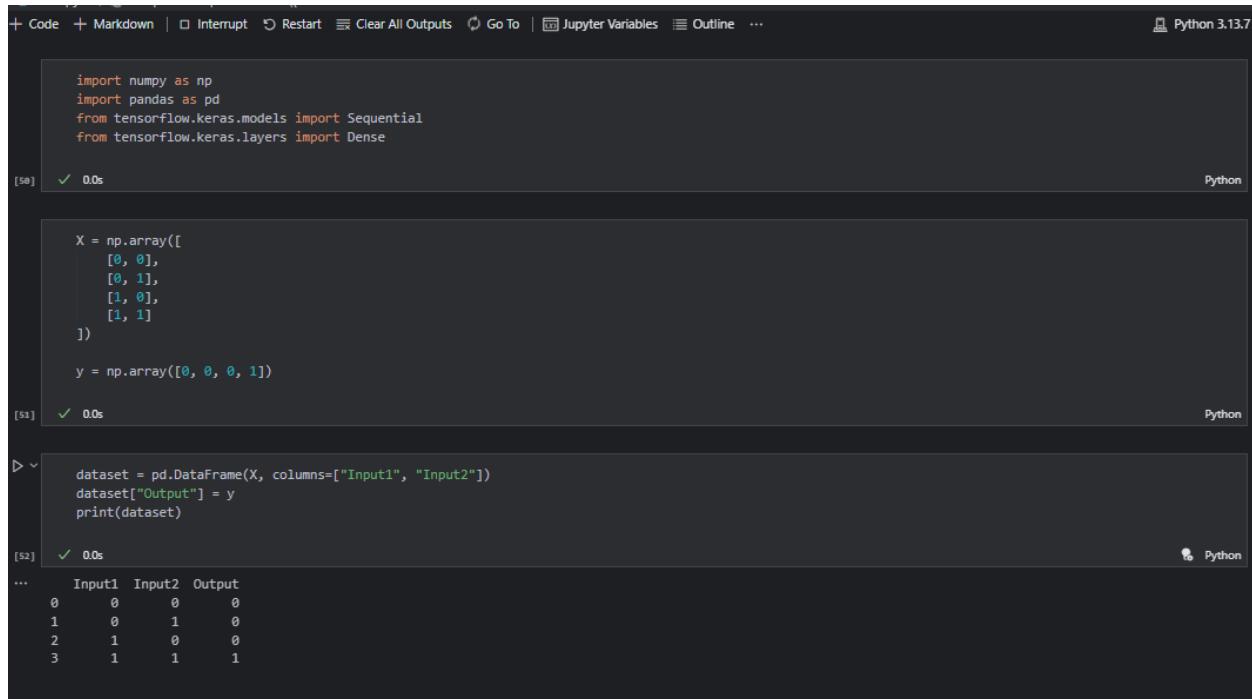
#### Question 1

Logic Gates with Neural Network. Implement a feed-forward neural network to learn the AND gate.

- Inputs: (0,0), (0,1), (1,0), (1,1)
- Output: 0, 0, 0, 1

#### Tasks:

1. Create dataset using NumPy or pandas.
2. Build a neural network with one hidden layer using TensorFlow/Keras or PyTorch.
3. Train it and show accuracy.
4. Compare model predictions with actual outputs



```
+ Code + Markdown | ⚡ Interrupt ⚡ Restart ⚡ Clear All Outputs ⚡ Go To | Jupyter Variables ⚡ Outline ...
```

Python 3.13.7

```
import numpy as np
import pandas as pd
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense
```

[50] ✓ 0.0s Python

```
X = np.array([
    [0, 0],
    [0, 1],
    [1, 0],
    [1, 1]
])

y = np.array([0, 0, 0, 1])
```

[51] ✓ 0.0s Python

```
dataset = pd.DataFrame(X, columns=["Input1", "Input2"])
dataset["Output"] = y
print(dataset)
```

[52] ✓ 0.0s Python

```
...   Input1  Input2  Output
0       0       0       0
1       0       1       0
2       1       0       0
3       1       1       1
```

```

model = Sequential()
model.add(Dense(4, input_dim=2, activation='relu'))
model.add(Dense(1, activation='sigmoid'))

[53] ✓ 0.0s
... c:\Users\h\AppData\Local\Programs\Python\Python313\Lib\site-packages\keras\src\layers\core\dense.py:95: UserWarning: Do not pass an `input_shape` / `input_dim` argument to `Dense`'s constructor. Instead, pass an integer to `input_dim` or a tuple/list to `input_shape` (e.g., (batch_size, input_dim)). If you are passing a 2D input tensor, consider using `Input` instead of `InputLayer` to define your input layer. See: https://keras.io/api/layers/core_layers/dense/
    super().__init__(activity_regularizer=activity_regularizer, **kwargs)

model.compile(
    optimizer='adam',
    loss='binary_crossentropy',
    metrics=['accuracy']
)

[54] ✓ 0.0s

model.fit(X, y, epochs=500, verbose=0)

[55] ✓ 55.0s
... <keras.src.callbacks.history.History at 0x15e27566780>

loss, accuracy = model.evaluate(X, y, verbose=0)
print("Model Accuracy:", accuracy)

[56] ✓ 0.0s
... Model Accuracy: 1.0

```

```

ipython3.13.7
comparison = pd.DataFrame({
    "Input1": X[:, 0],
    "Input2": X[:, 1],
    "Actual Output": y,
    "Predicted Output": predicted_output.flatten()
})
print(comparison)

[57] ✓ 0.1s
... 1/1 ━━━━━━ 0s 108ms/step

predicted_output = (predictions > 0.5).astype(int)

[58] ✓ 0.0s

```

```

ipython3.13.7
comparison = pd.DataFrame({
    "Input1": X[:, 0],
    "Input2": X[:, 1],
    "Actual Output": y,
    "Predicted Output": predicted_output.flatten()
})
print(comparison)

[59] ✓ 0.0s
...      Input1  Input2  Actual Output  Predicted Output
  0        0       0             0            0
  1        0       1             0            0
  2        1       0             0            0
  3        1       1             1            1

```

## Question 2

Create a dataset  $y = x^2 + \text{noise}$  for  $x$  in range  $[-3,3]$ . Regression Task with Neural Network

Tasks:

1. Generate 100 samples.
2. Build a neural network to predict y from x.
3. Plot actual vs. predicted results.
4. Discuss how increasing hidden neurons changes results.

```

+ Code + Markdown | ▶ Run All ⏪ Restart ⏴ Clear All Outputs | Jupyter Variables | Outline ...
Python 3.13.7

[7] ✓ 0.0s

import numpy as np
import matplotlib.pyplot as plt

np.random.seed(0)

# 100 samples in range [-3,3]
x = np.linspace(-3, 3, 100).reshape(-1, 1)
noise = np.random.randn(100,1) * 0.5
y = x**2 + noise

```

[8] ✓ 0.0s

```

# Network architecture
input_neurons = 1
hidden_neurons = 8
output_neurons = 1

# Initialize weights and biases
W1 = np.random.randn(input_neurons, hidden_neurons)
b1 = np.zeros((1, hidden_neurons))

W2 = np.random.randn(hidden_neurons, output_neurons)
b2 = np.zeros((1, output_neurons))

# Activation function
def relu(z):
    return np.maximum(0, z)

def relu_derivative(z):
    return (z > 0).astype(float)

```

[9] ✓ 0.0s

```

+ Code + Markdown | ▶ Run All ⏪ Restart ⏴ Clear All Outputs | Jupyter Variables | Outline ...
Python 3.13.7

learning_rate = 0.01
epochs = 2000

for epoch in range(epochs):
    # Forward pass
    z1 = x @ W1 + b1
    a1 = relu(z1)
    z2 = a1 @ W2 + b2
    y_pred = z2 # Linear output for regression

    # Loss (MSE)
    loss = np.mean((y_pred - y)**2)

    # Backpropagation
    dloss = 2*(y_pred - y)/y.size
    dw2 = a1.T @ dloss
    db2 = np.sum(dloss, axis=0, keepdims=True)

    da1 = dloss @ W2.T
    dz1 = da1 * relu_derivative(z1)
    dw1 = x.T @ dz1
    db1 = np.sum(dz1, axis=0, keepdims=True)

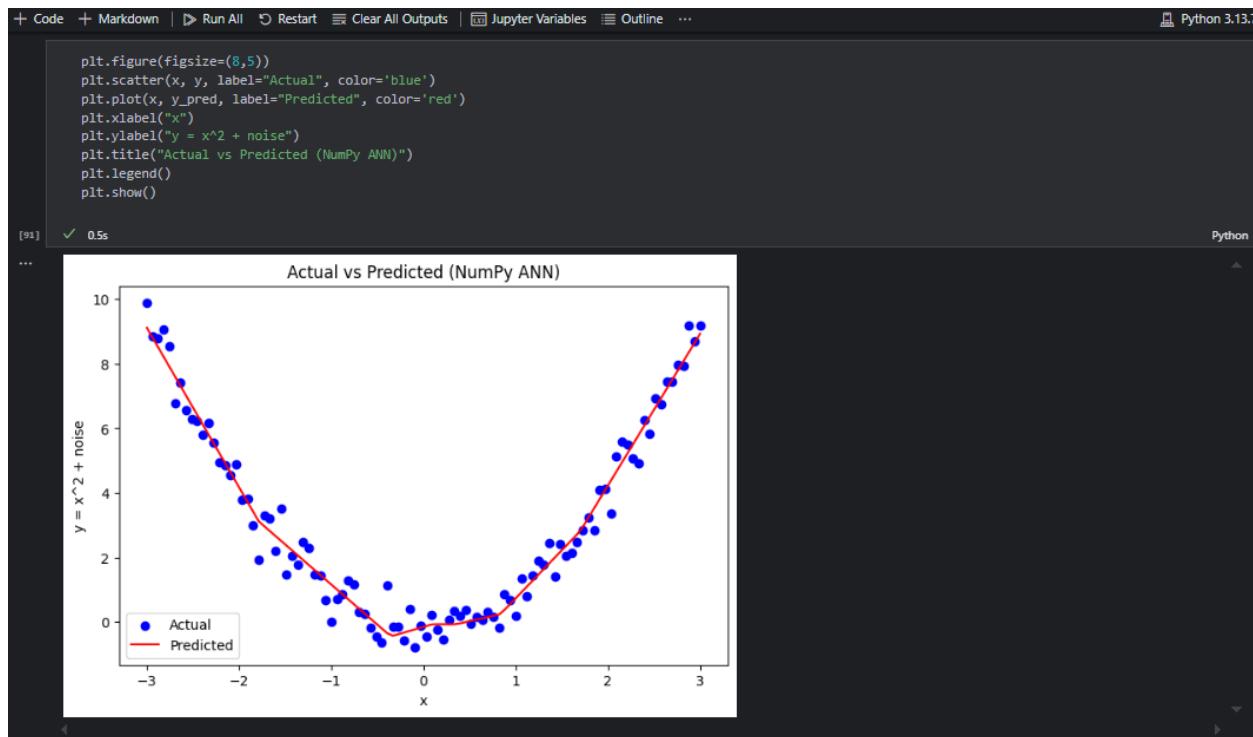
    # Update weights
    W2 -= learning_rate * dw2
    b2 -= learning_rate * db2
    W1 -= learning_rate * dw1
    b1 -= learning_rate * db1

    if (epoch+1) % 500 == 0:
        print(f"Epoch {epoch+1}, Loss: {loss:.4f}")

```

[98] ✓ 0.5s

... Epoch 500, Loss: 0.3950  
Epoch 1000, Loss: 0.2915  
Epoch 1500, Loss: 0.2392  
Epoch 2000, Loss: 0.2207



### Question 3:

Use the XOR gate and train networks with different activation functions (sigmoid, tanh, ReLU).

- Compare accuracy, loss, and convergence speed.
- Plot and discuss results.

```

# lab5.ipynb > plt.figure(figsize=(10,5))

+ Code + Markdown | Run All | Restart | Clear All Outputs | Jupyter Variables | Outline ... Python 3.13.7

[110] ✓ 0.0s

import numpy as np
import matplotlib.pyplot as plt

[111] ✓ 0.0s

# Inputs
X = np.array([[0,0],[0,1],[1,0],[1,1]])
y = np.array([[0],[1],[1],[0]])

[112] ✓ 0.0s

def sigmoid(x):
    return 1 / (1 + np.exp(-x))

def sigmoid_derivative(x):
    s = sigmoid(x)
    return s * (1 - s)

def tanh(x):
    return np.tanh(x)

def tanh_derivative(x):
    return 1 - np.tanh(x)**2

def relu(x):
    return np.maximum(0, x)

def relu_derivative(x):
    return (x > 0).astype(float)

```

```

def train_xor(activation, activation_derivative, hidden_neurons=4, lr=0.1, epochs=10000):
    # Initialize weights
    np.random.seed(0)
    W1 = np.random.randn(2, hidden_neurons)
    b1 = np.zeros((1, hidden_neurons))
    W2 = np.random.randn(hidden_neurons, 1)
    b2 = np.zeros((1,1))

    losses = []

    for epoch in range(epochs):
        # Forward pass
        z1 = X @ W1 + b1
        a1 = activation(z1)
        z2 = a1 @ W2 + b2
        y_pred = sigmoid(z2) # Output layer always sigmoid

        # Loss
        loss = np.mean((y_pred - y)**2)
        losses.append(loss)

        # Backpropagation
        dloss = 2*(y_pred - y)/y.size
        dz2 = dloss * sigmoid_derivative(z2)
        dW2 = a1.T @ dz2
        db2 = np.sum(dz2, axis=0, keepdims=True)

        da1 = dz2 @ W2.T
        dz1 = da1 * activation_derivative(z1)
        dW1 = X.T @ dz1
        db1 = np.sum(dz1, axis=0, keepdims=True)

        # Update weights
        W2 -= lr * dW2
        b2 -= lr * db2
        W1 -= lr * dW1
        b1 -= lr * db1

```

The screenshot shows a Jupyter Notebook interface with several code cells and their outputs.

```

# Update weights
W2 -= lr * dW2
b2 -= lr * db2
W1 -= lr * dW1
b1 -= lr * db1

# Final predictions
final_pred = (y_pred > 0.5).astype(int)
accuracy = np.mean(final_pred == y)
return losses, accuracy, final_pred

```

[113] ✓ 0.0s Python

```

# Sigmoid
loss_sigmoid, acc_sigmoid, pred_sigmoid = train_xor(sigmoid, sigmoid_derivative)

# Tanh
loss_tanh, acc_tanh, pred_tanh = train_xor(tanh, tanh_derivative)

# ReLU
loss_relu, acc_relu, pred_relu = train_xor(rectify, rectify_derivative)

```

[114] ✓ 5.2s Python

```

print("Accuracy with Sigmoid:", acc_sigmoid)
print("Accuracy with Tanh   :", acc_tanh)
print("Accuracy with ReLU   :", acc_relu)

```

[115] ✓ 0.0s Python

... Accuracy with Sigmoid: 1.0  
Accuracy with Tanh : 1.0  
Accuracy with ReLU : 1.0



## Question 4

### Binary Classification using Neural Network

**Objective:** Build a neural network to classify whether a tumor is malignant or benign using the **Breast Cancer dataset**.

```

Code + Markdown | Run All ⏪ Restart ⏴ Clear All Outputs | Jupyter Variables ⏴ Outline ... Python 3.13.7
> v
    import numpy as np
    import pandas as pd
    import matplotlib.pyplot as plt
    from sklearn.datasets import load_breast_cancer
    from sklearn.model_selection import train_test_split
    from sklearn.preprocessing import StandardScaler

181] ✓ 0.0s

```

```

    data = load_breast_cancer()
    X = data.data
    y = data.target.reshape(-1,1) # 0 = malignant, 1 = benign

    # Train-test split
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

    # Feature scaling
    scaler = StandardScaler()
    X_train = scaler.fit_transform(X_train)
    X_test = scaler.transform(X_test)

182] ✓ 0.0s

```

```

    def sigmoid(x):
        return 1 / (1 + np.exp(-x))

    def sigmoid_derivative():
        s = sigmoid(x)
        return s * (1 - s)

183] ✓ 0.0s

```

```
[184] ✓ 0.0s Python

    input_neurons = X_train.shape[1]
    hidden_neurons = 16
    output_neurons = 1

    np.random.seed(0)
    W1 = np.random.randn(input_neurons, hidden_neurons) * 0.01
    b1 = np.zeros((1, hidden_neurons))
    W2 = np.random.randn(hidden_neurons, output_neurons) * 0.01
    b2 = np.zeros((1, output_neurons))
```

```
[185] ✓ 0.0s Python

    lr = 0.01
    epochs = 5000
    losses = []

    for epoch in range(epochs):
        # Forward pass
        z1 = X_train @ W1 + b1
        a1 = sigmoid(z1)
        z2 = a1 @ W2 + b2
        y_pred = sigmoid(z2)

        # Loss (Binary Cross-Entropy)
        loss = -np.mean(y_train*np.log(y_pred+1e-8) + (1-y_train)*np.log(1-y_pred+1e-8))
        losses.append(loss)

        # Backpropagation
        dloss = y_pred - y_train
        dW2 = a1.T @ dloss
        db2 = np.sum(dloss, axis=0, keepdims=True)

        da1 = dloss @ W2.T
        dz1 = da1 * sigmoid_derivative(z1)
        dW1 = X_train.T @ dz1
```

```
[185] ✓ 4.3s Python

    # Loss (Binary Cross-Entropy)
    loss = -np.mean(y_train*np.log(y_pred+1e-8) + (1-y_train)*np.log(1-y_pred+1e-8))
    losses.append(loss)

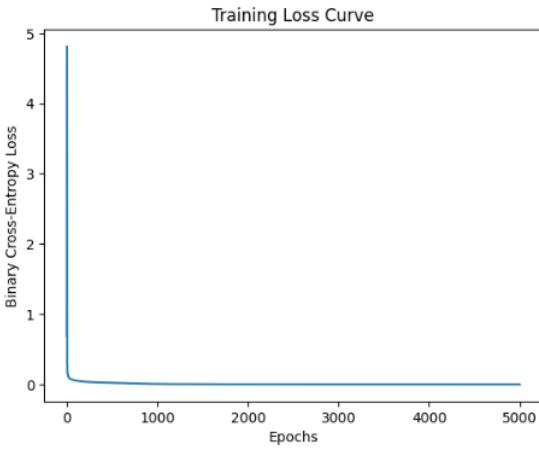
    # Backpropagation
    dloss = y_pred - y_train
    dW2 = a1.T @ dloss
    db2 = np.sum(dloss, axis=0, keepdims=True)

    da1 = dloss @ W2.T
    dz1 = da1 * sigmoid_derivative(z1)
    dW1 = X_train.T @ dz1
    db1 = np.sum(dz1, axis=0, keepdims=True)

    # Update weights
    W2 -= lr * dW2
    b2 -= lr * db2
    W1 -= lr * dW1
    b1 -= lr * db1

    if (epoch+1) % 500 == 0:
        print(f"Epoch {epoch+1}, Loss: {loss:.4f}")

Epoch 500, Loss: 0.0229
Epoch 1000, Loss: 0.0062
Epoch 1500, Loss: 0.0023
Epoch 2000, Loss: 0.0012
Epoch 2500, Loss: 0.0008
Epoch 3000, Loss: 0.0006
Epoch 3500, Loss: 0.0005
Epoch 4000, Loss: 0.0004
Epoch 4500, Loss: 0.0003
Epoch 5000, Loss: 0.0003
```

```
+ Code + Markdown | ▶ Run All ⌂ Restart ⌂ Clear All Outputs | Jupyter Variables ⌂ Outline ... Python 3.13.  
Epoch 5000, Loss: 0.0006  
Epoch 3500, Loss: 0.0005  
Epoch 4000, Loss: 0.0004  
Epoch 4500, Loss: 0.0003  
Epoch 5000, Loss: 0.0003  
  
▶ [186] train_pred = (y_pred > 0.5).astype(int)  
      train_accuracy = np.mean(train_pred == y_train)  
      print("Training Accuracy:", train_accuracy)  
Success  
[186] ✓ 0.0s Python  
... Training Accuracy: 1.0  
  
# Forward pass on test set  
a1_test = sigmoid(X_test @ W1 + b1)  
y_test_pred = sigmoid(a1_test @ W2 + b2)  
y_test_pred_binary = (y_test_pred > 0.5).astype(int)  
  
test_accuracy = np.mean(y_test_pred_binary == y_test)  
print("Test Accuracy:", test_accuracy)  
  
[187] ✓ 0.0s Python  
... Test Accuracy: 0.9736842105263158  
  
▶ [188] plt.plot(losses)  
      plt.xlabel("Epochs")  
      plt.ylabel("Binary Cross-Entropy Loss")  
      plt.title("Training Loss Curve")  
      plt.show()  
  
[188] ✓ 0.4s Python  
..  
Training Loss Curve  

```

## Question 5

### Multi-Class Classification on Iris Dataset

**Objective:** Train a neural network to classify flower species (Setosa, Versicolor, Virginica).

```

lab5.ipynb > plt.plot(losses)
+ Code + Markdown | ▶ Run All ⚡ Restart ⚡ Clear All Outputs | Jupyter Variables ⚡ Outline ...
Python 3.13.7

import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler, OneHotEncoder
import matplotlib.pyplot as plt

[235] ✓ 0.0s Python

# CSV file path
data = pd.read_csv("iris_data.csv") # Replace with your CSV file name

# Check first few rows
print(data.head())

[236] ✓ 0.0s Python

...    sepal length (cm)  sepal width (cm)  petal length (cm)  petal width (cm) \
0           5.1          3.5            1.4             0.2
1           4.9          3.0            1.4             0.2
2           4.7          3.2            1.3             0.2
3           4.6          3.1            1.5             0.2
4           5.0          3.6            1.4             0.2

   species
0  setosa
1  setosa
2  setosa
3  setosa
4  setosa

# Features (all columns except last)
X = data.iloc[:, :-1].values

[237] ✓ 0.0s Python

lab5.ipynb > plt.plot(losses)
+ Code + Markdown | ▶ Run All ⚡ Restart ⚡ Clear All Outputs | Jupyter Variables ⚡ Outline ...
Python 3.13.7

[237] ✓ 0.0s Python

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

# Standardize features
scaler = StandardScaler()
X_train = scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)

[238] ✓ 0.0s Python

def sigmoid(x):
    return 1 / (1 + np.exp(-x))

def sigmoid_derivative(x):
    s = sigmoid(x)
    return s * (1 - s)

def softmax(x):
    exp_x = np.exp(x - np.max(x, axis=1, keepdims=True))
    return exp_x / np.sum(exp_x, axis=1, keepdims=True)

[239] ✓ 0.0s Python

D ✓
input_neurons = X_train.shape[1] # 4 features
hidden_neurons = 8
output_neurons = y_train.shape[1] # 3 classes

np.random.seed(0)
W1 = np.random.randn(input_neurons, hidden_neurons) * 0.01
b1 = np.zeros((1, hidden_neurons))
W2 = np.random.randn(hidden_neurons, output_neurons) * 0.01
b2 = np.zeros((1, output_neurons))

[240] ✓ 0.0s Python

```

Q | Ln 11, Col 1 | Spaces: 4 | Spaces: 4 | CRLF | Cell 9 of 9 | ⌂ | ⌂

```
# Backpropagation
dloss = (y_pred - y_train)/y_train.shape[0]
dw2 = a1.T @ dloss
db2 = np.sum(dloss, axis=0, keepdims=True)

da1 = dloss @ W2.T
dz1 = da1 * sigmoid_derivative(z1)
dw1 = X_train.T @ dz1
db1 = np.sum(dz1, axis=0, keepdims=True)

# Update weights
W2 -= lr * dw2
b2 -= lr * db2
W1 -= lr * dw1
b1 -= lr * db1

if (epoch+1) % 500 == 0:
    print(f"Epoch {epoch+1}, Loss: {loss:.4f}")

[41] ✓ 2.7s
```

.. Epoch 500, Loss: 0.6236  
Epoch 1000, Loss: 0.3484  
Epoch 1500, Loss: 0.2495  
Epoch 2000, Loss: 0.1868  
Epoch 2500, Loss: 0.1478  
Epoch 3000, Loss: 0.1240  
Epoch 3500, Loss: 0.1086  
Epoch 4000, Loss: 0.0980  
Epoch 4500, Loss: 0.0903  
Epoch 5000, Loss: 0.0845

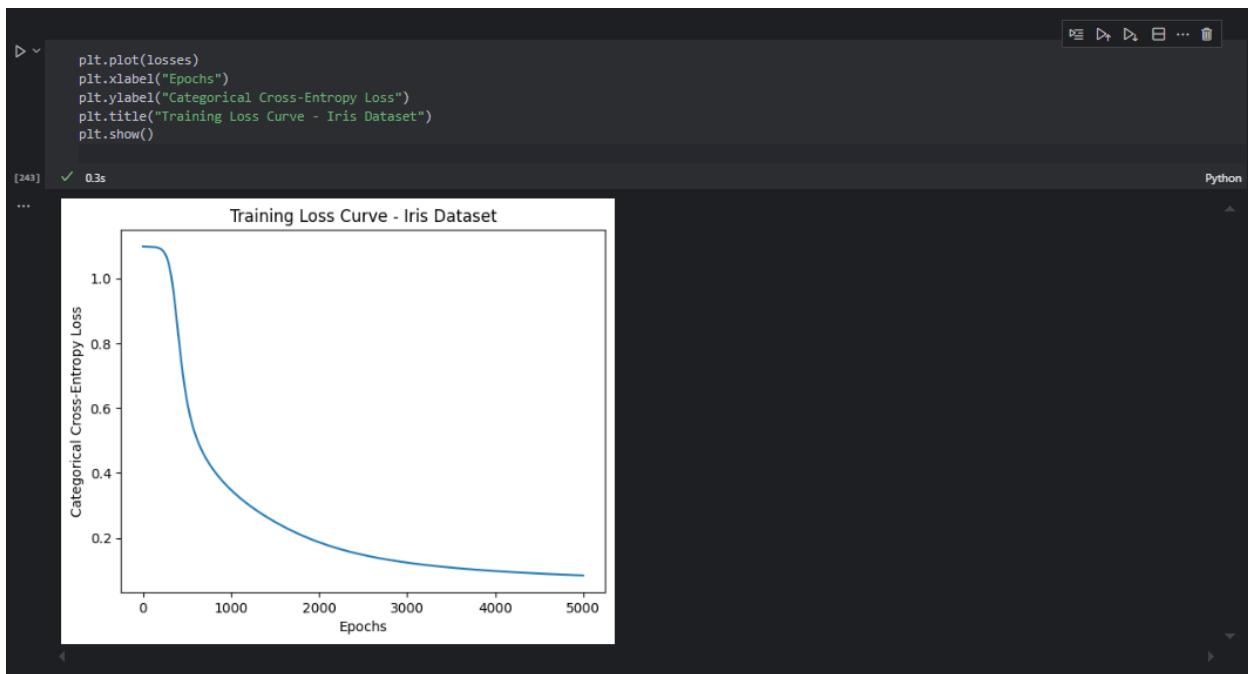
```
# Training accuracy
train_pred = np.argmax(y_pred, axis=1)
y_train_labels = np.argmax(y_train, axis=1)
train_accuracy = np.mean(train_pred == y_train_labels)
print("Training Accuracy:", train_accuracy)

# Test accuracy
a1_test = sigmoid(X_test @ W1 + b1)
y_test_pred = softmax(a1_test @ W2 + b2)
test_pred_labels = np.argmax(y_test_pred, axis=1)
y_test_labels = np.argmax(y_test, axis=1)
test_accuracy = np.mean(test_pred_labels == y_test_labels)
print("Test Accuracy:", test_accuracy)

[242] ✓ 0.0s
.. Training Accuracy: 0.9583333333333334
Test Accuracy: 1.0
```

▷ `plt.plot(losses)`  
`plt.xlabel("Epochs")`  
`plt.ylabel("Categorical Cross-Entropy Loss")`  
`plt.title("Training Loss Curve - Iris Dataset")`  
`plt.show()`

```
[243] ✓ 0.3s
```



## Question 6

### Regression Problem (House Price Prediction)

**Objective:** Predict house prices using the California Housing dataset.

```

+ Code + Markdown | ▶ Run All ⚡ Restart ⏷ Clear All Outputs | 📈 Jupyter Variables | 🔍 Outline ... Python 3.13
D ...
for e in range(epochs):
    # Forward
    a1 = sigmoid(X_train @ W1 + b1)
    y_pred = a1 @ W2 + b2

    # Loss
    loss = np.mean((y_train - y_pred)**2)
    losses.append(loss)

    # Backprop & update
    dW2 = a1.T @ (2*(y_pred - y_train)/y_train.shape[0])
    db2 = np.sum(2*(y_pred - y_train)/y_train.shape[0], axis=0, keepdims=True)
    dz1 = (2*(y_pred - y_train)/y_train.shape[0]) @ W2.T * a1*(1-a1)
    dW1 = X_train.T @ dz1
    db1 = np.sum(dz1, axis=0, keepdims=True)

    W2 -= lr*dW2; b2 -= lr*db2
    W1 -= lr*dW1; b1 -= lr*db1

    if (e+1) % 200 == 0:
        print(f"Epoch {e+1}, Loss: {loss:.4f}")

[282]  ✓  35.8s
...
Epoch 200, Loss: 0.9993
Epoch 400, Loss: 0.9968
Epoch 600, Loss: 0.9872
Epoch 800, Loss: 0.9511
Epoch 1000, Loss: 0.8464
Epoch 1200, Loss: 0.6709
Epoch 1400, Loss: 0.5312
Epoch 1600, Loss: 0.4710
Epoch 1800, Loss: 0.4483
Epoch 2000, Loss: 0.4356

```

```

Epoch 800, Loss: 0.9511
Epoch 1000, Loss: 0.8464
Epoch 1200, Loss: 0.6709
Epoch 1400, Loss: 0.5312
Epoch 1600, Loss: 0.4710
Epoch 1800, Loss: 0.4483
Epoch 2000, Loss: 0.4356

[283] a1_test = sigmoid(X_test @ W1 + b1)
      y_test_pred = a1_test @ W2 + b2

      y_test_pred_orig = scaler_y.inverse_transform(y_test_pred)
      y_test_orig = scaler_y.inverse_transform(y_test)

      print("R² Score:", r2_score(y_test_orig, y_test_pred_orig))
      print("MSE:", mean_squared_error(y_test_orig, y_test_pred_orig))

[283]   ✓ 0.0s
...   R² Score: 0.545118164526881
      MSE: 0.5960812412426748

[284] ▶ plt.scatter(y_test_orig, y_test_pred_orig, alpha=0.5)
      plt.plot([y_test_orig.min(), y_test_orig.max()], [y_test_orig.min(), y_test_orig.max()], 'r--')
      plt.xlabel("Actual Price")
      plt.ylabel("Predicted Price")
      plt.title("Actual vs Predicted House Prices")
      plt.show()
      |
[284]   ✓ 0.7s
...

```

Code execution results:

```

+ Code + Markdown | ▶ Run All ⏪ Restart ⏪ Clear All Outputs | Jupyter Variables | Outline ... Python 3.13.7
[284] plt.scatter(y_test_orig, y_test_pred_orig, alpha=0.5)
      plt.plot([y_test_orig.min(), y_test_orig.max()], [y_test_orig.min(), y_test_orig.max()], 'r--')
      plt.xlabel("Actual Price")
      plt.ylabel("Predicted Price")
      plt.title("Actual vs Predicted House Prices")
      plt.show()

[284]   ✓ 0.7s
...
```

## Question 7

### Neural Network with Dropout Regularization

**Objective:** Prevent overfitting using Dropout layers on the MNIST digit dataset.

```
Code + Markdown | ▶ Run All ⚡ Restart ⏷ Clear All Outputs | Jupyter Variables | Outline ... Python
```

```
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, Flatten
from tensorflow.keras.datasets import mnist
from tensorflow.keras.utils import to_categorical
import matplotlib.pyplot as plt

88] ✓ 0.0s
```

```
# Load MNIST
(x_train, y_train), (x_test, y_test) = mnist.load_data()

# Normalize images
x_train, x_test = x_train/255.0, x_test/255.0

# One-hot encode labels
y_train = to_categorical(y_train, 10)
y_test = to_categorical(y_test, 10)

99] ✓ 1.3s
```

```
model = Sequential([
    Flatten(input_shape=(28,28)),      # Flatten 28x28 images
    Dense(128, activation='relu'),     # 128 units
    Dropout(0.3),                   # Dropout 30%
    Dense(64, activation='relu'),     # 64 units
    Dropout(0.3),                   # Dropout 30%
    Dense(10, activation='softmax')   # Output layer for 10 classes
])
```

```
100] ✓ 0.1s
```

```
Code + Markdown | ▶ Run All ⚡ Restart ⏷ Clear All Outputs | Jupyter Variables | Outline ... Python 3.13.7
```

```
model = Sequential([
    Flatten(input_shape=(28,28)),      # Flatten 28x28 images
    Dense(128, activation='relu'),     # 128 units
    Dropout(0.3),                   # Dropout 30%
    Dense(64, activation='relu'),     # 64 units
    Dropout(0.3),                   # Dropout 30%
    Dense(10, activation='softmax')   # Output layer for 10 classes
])
```

```
300] ✓ 0.1s
```

```
model.compile(
    optimizer='adam',
    loss='categorical_crossentropy',
    metrics=['accuracy']
)
```

```
301] ✓ 0.0s
```

```
> v
history = model.fit(
    x_train, y_train,
    validation_split=0.2,
    epochs=20,
    batch_size=128,
    verbose=1
)
```

```
302] ✓ 1m 22.0s
```

```
... Epoch 1/20
375/375 7s 10ms/step - accuracy: 0.8199 - loss: 0.5910 - val_accuracy: 0.9426 - val_loss: 0.1983
Epoch 2/20
375/375 3s 8ms/step - accuracy: 0.9249 - loss: 0.2614 - val_accuracy: 0.9582 - val_loss: 0.1476
Epoch 3/20
```

lab3.ipynb > history = model.history

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```
loss, accuracy = model.evaluate(x_test, y_test)
print("Test Loss:", loss)
print("Test Accuracy:", accuracy)

[3/3] ✓ 1.7s
...
313/313 2s 5ms/step - accuracy: 0.9799 - loss: 0.0717
Test Loss: 0.071674905173729
Test Accuracy: 0.9799000024795532
```