Applied Problem 1

In [ ]:

```
def compile_and_train(model, x_train, y_train, x_val, y_val):
    model.compile(optimizer='adam', loss='sparse_categorical_crossentropy', metrics=['ac
curacy'])
    history = model.fit(x_train, y_train, epochs=10, validation_data=(x_val, y_val), bat
ch_size=32)
    return history
```

Importing Libraries

In [ ]:

```
import random
import numpy as np
import seaborn as sns
import tensorflow as tf

from matplotlib import pyplot as plt
from sklearn.model_selection import train_test_split
from tensorflow.keras.datasets import fashion_mnist
from tensorflow.keras.layers import Conv2D, Dense, Flatten, LeakyReLU, MaxPooling2D
from tensorflow.keras.models import Sequential
```

Data Handling

In [ ]:

```
tf.random.set_seed(42)
np.random.seed(42)
random.seed(42)
```

In [ ]:

```
# Load the Fashion MNIST dataset
(x_train_full, y_train_full), (x_test, y_test) = fashion_mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-l
abels-idx1-ubyte.gz
29515/29515 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-i
mages-idx3-ubyte.gz
26421880/26421880 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-la
bels-idx1-ubyte.gz
5148/5148 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-im
ages-idx3-ubyte.gz
4422102/4422102 [==============================] - 0s 0us/step
```

In [ ]:

```
# Normalize the data
x_train_full = x_train_full / 255.0
x_test = x_test / 255.0
```

In [ ]:

```
# Split the training set into separate training and validation sets
x_train, x_val, y_train, y_val = train_test_split(x_train_full, y_train_full, test_size=
0.2, random_state=42)
```

One-Layer Model

In [ ]:

```
def build_model(activation_function, num_neurons):
    if activation_function == 'leaky_relu':
        model = Sequential([
            Flatten(input_shape=(28, 28)),  # Flatten the input
            Dense(num_neurons),  # Hidden layer with 'p' neurons
            LeakyReLU(alpha=0.01),  # LeakyReLU with a small slope
            Dense(10, activation='softmax')  # Output layer for 10 classes
        ])
    else:
        model = Sequential([
            Flatten(input_shape=(28, 28)),  # Flatten the input
            Dense(num_neurons, activation=activation_function),  # Hidden layer with 'p'
neurons
            Dense(10, activation='softmax')  # Output layer for 10 classes
        ])
    return model
```

Validation Loop

In [ ]:

```
neuron_choices = [64, 128, 256]

best_leaky_model = None
best_leaky_accuracy = 0
best_model = None
best_accuracy = 0

for num_neurons in neuron_choices:
    model = build_model('relu', num_neurons)
    leaky_model = build_model('leaky_relu', num_neurons)

    history = compile_and_train(model, x_train, y_train, x_val, y_val)
    leaky_history = compile_and_train(leaky_model, x_train, y_train, x_val, y_val)

    if max(history.history['val_accuracy']) > best_accuracy:
        best_accuracy = max(history.history['val_accuracy'])
        best_model = model

    if max(leaky_history.history['val_accuracy']) > best_leaky_accuracy:
        best_leaky_accuracy = max(leaky_history.history['val_accuracy'])
        best_leaky_model = leaky_model
```

```
Epoch 1/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.5363 - accuracy: 0.813
4 - val_loss: 0.4400 - val_accuracy: 0.8417
Epoch 2/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.4049 - accuracy: 0.856
6 - val_loss: 0.3905 - val_accuracy: 0.8600
Epoch 3/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.3684 - accuracy: 0.867
2 - val_loss: 0.3810 - val_accuracy: 0.8659
Epoch 4/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3449 - accuracy: 0.876
1 - val_loss: 0.3568 - val_accuracy: 0.8740
Epoch 5/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3250 - accuracy: 0.881
7 - val_loss: 0.3619 - val_accuracy: 0.8708
Epoch 6/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3095 - accuracy: 0.886
6 - val_loss: 0.3385 - val_accuracy: 0.8800
Epoch 7/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2970 - accuracy: 0.891
6 - val_loss: 0.3337 - val_accuracy: 0.8793
```

```
Epoch 8/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.2853 - accuracy: 0.894
2 - val_loss: 0.3380 - val_accuracy: 0.8788
Epoch 9/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2771 - accuracy: 0.897
0 - val_loss: 0.3298 - val_accuracy: 0.8842
Epoch 10/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2666 - accuracy: 0.901
8 - val_loss: 0.3323 - val_accuracy: 0.8834
Epoch 1/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.5332 - accuracy: 0.814
2 - val_loss: 0.4445 - val_accuracy: 0.8439
Epoch 2/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.4013 - accuracy: 0.858
1 - val_loss: 0.3896 - val_accuracy: 0.8623
Epoch 3/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.3659 - accuracy: 0.867
8 - val_loss: 0.3831 - val_accuracy: 0.8652
Epoch 4/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3402 - accuracy: 0.877
1 - val_loss: 0.3500 - val_accuracy: 0.8758
Epoch 5/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.3209 - accuracy: 0.882
7 - val_loss: 0.3450 - val_accuracy: 0.8749
Epoch 6/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3034 - accuracy: 0.889
8 - val_loss: 0.3347 - val_accuracy: 0.8808
Epoch 7/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2931 - accuracy: 0.892
2 - val_loss: 0.3319 - val_accuracy: 0.8806
Epoch 8/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2814 - accuracy: 0.895
8 - val_loss: 0.3278 - val_accuracy: 0.8808
Epoch 9/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2711 - accuracy: 0.899
4 - val_loss: 0.3254 - val_accuracy: 0.8838
Epoch 10/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.2631 - accuracy: 0.902
7 - val_loss: 0.3380 - val_accuracy: 0.8788
Epoch 1/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.5203 - accuracy: 0.818
6 - val_loss: 0.4275 - val_accuracy: 0.8455
Epoch 2/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.3890 - accuracy: 0.860
0 - val_loss: 0.3838 - val_accuracy: 0.8622
Epoch 3/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3499 - accuracy: 0.872
7 - val_loss: 0.3566 - val_accuracy: 0.8753
Epoch 4/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3258 - accuracy: 0.881
9 - val_loss: 0.3402 - val_accuracy: 0.8788
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3043 - accuracy: 0.887
6 - val_loss: 0.3304 - val_accuracy: 0.8808
Epoch 6/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2886 - accuracy: 0.894
2 - val_loss: 0.3274 - val_accuracy: 0.8828
Epoch 7/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2768 - accuracy: 0.897
3 - val_loss: 0.3179 - val_accuracy: 0.8848
Epoch 8/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2648 - accuracy: 0.901
2 - val_loss: 0.3158 - val_accuracy: 0.8888
Epoch 9/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2532 - accuracy: 0.904
9 - val_loss: 0.3201 - val_accuracy: 0.8885
Epoch 10/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2438 - accuracy: 0.908
9 - val_loss: 0.3356 - val_accuracy: 0.8806
Epoch 1/10
1500/1500 [==============================] - 9s 5ms/step - loss: 0.5182 - accuracy: 0.818
1 - val_loss: 0.4296 - val_accuracy: 0.8450
```

```
Epoch 2/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3847 - accuracy: 0.860
6 - val_loss: 0.3768 - val_accuracy: 0.8619
Epoch 3/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.3471 - accuracy: 0.873
6 - val_loss: 0.3625 - val_accuracy: 0.8718
Epoch 4/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3226 - accuracy: 0.882
1 - val_loss: 0.3421 - val_accuracy: 0.8764
Epoch 5/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3011 - accuracy: 0.888
2 - val_loss: 0.3618 - val_accuracy: 0.8699
Epoch 6/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2851 - accuracy: 0.896
0 - val_loss: 0.3312 - val_accuracy: 0.8802
Epoch 7/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2734 - accuracy: 0.897
8 - val_loss: 0.3148 - val_accuracy: 0.8866
Epoch 8/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2606 - accuracy: 0.902
3 - val_loss: 0.3269 - val_accuracy: 0.8840
Epoch 9/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.2503 - accuracy: 0.906
6 - val_loss: 0.3210 - val_accuracy: 0.8855
Epoch 10/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2393 - accuracy: 0.910
6 - val_loss: 0.3317 - val_accuracy: 0.8827
Epoch 1/10
1500/1500 [==============================] - 9s 5ms/step - loss: 0.5023 - accuracy: 0.821
4 - val_loss: 0.4415 - val_accuracy: 0.8335
Epoch 2/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.3748 - accuracy: 0.86
39 - val_loss: 0.3743 - val_accuracy: 0.8643
Epoch 3/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3351 - accuracy: 0.877
1 - val_loss: 0.3493 - val_accuracy: 0.8751
Epoch 4/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3113 - accuracy: 0.886
3 - val_loss: 0.3431 - val_accuracy: 0.8767
Epoch 5/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2890 - accuracy: 0.89
30 - val_loss: 0.3426 - val_accuracy: 0.8764
Epoch 6/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2740 - accuracy: 0.899
3 - val_loss: 0.3169 - val_accuracy: 0.8852
Epoch 7/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2630 - accuracy: 0.90
12 - val_loss: 0.3102 - val_accuracy: 0.8881
Epoch 8/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2512 - accuracy: 0.90
52 - val_loss: 0.3176 - val_accuracy: 0.8892
Epoch 9/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2384 - accuracy: 0.910
3 - val_loss: 0.3237 - val_accuracy: 0.8882
Epoch 10/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2291 - accuracy: 0.91
57 - val_loss: 0.3391 - val_accuracy: 0.8852
Epoch 1/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.4968 - accuracy: 0.82
42 - val_loss: 0.4224 - val_accuracy: 0.8477
Epoch 2/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3713 - accuracy: 0.866
0 - val_loss: 0.3668 - val_accuracy: 0.8697
Epoch 3/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.3332 - accuracy: 0.87
71 - val_loss: 0.3529 - val_accuracy: 0.8737
Epoch 4/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3099 - accuracy: 0.885
1 - val_loss: 0.3247 - val_accuracy: 0.8813
Epoch 5/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2895 - accuracy: 0.892
6 - val_loss: 0.3486 - val_accuracy: 0.8753
```

```
Epoch 6/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2732 - accuracy: 0.89
92 - val_loss: 0.3154 - val_accuracy: 0.8848
Epoch 7/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2623 - accuracy: 0.902
0 - val_loss: 0.3112 - val_accuracy: 0.8855
Epoch 8/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2493 - accuracy: 0.906
1 - val_loss: 0.3095 - val_accuracy: 0.8903
Epoch 9/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2381 - accuracy: 0.91
06 - val_loss: 0.3103 - val_accuracy: 0.8886
Epoch 10/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2285 - accuracy: 0.914
9 - val_loss: 0.3323 - val_accuracy: 0.8832
```

Evaluate Models on Testing Data

In [ ]:

```
# Evaluate the best model on the test set
test_loss, test_accuracy = best_model.evaluate(x_test, y_test)
print(f"ReLU Test Loss: {test_loss}, ReLU Test Accuracy: {test_accuracy}")

leaky_test_loss, leaky_test_accuracy = best_leaky_model.evaluate(x_test, y_test)
print(f"Leaky ReLU Test Loss: {leaky_test_loss}, Leaky ReLU Test Accuracy: {leaky_test_ac
curacy}")
```

```
313/313 [==============================] - 1s 2ms/step - loss: 0.3648 - accuracy: 0.8772
ReLU Test Loss: 0.3648383915424347, ReLU Test Accuracy: 0.8772000074386597
313/313 [==============================] - 1s 2ms/step - loss: 0.3643 - accuracy: 0.8738
Leaky ReLU Test Loss: 0.36434975266456604, Leaky ReLU Test Accuracy: 0.8737999796867371
```

Compare with Different Activation Function

In [ ]:

```
neuron_choices = [64, 128, 256]

best_tanh_model = None
best_tanh_accuracy = 0

for num_neurons in neuron_choices:
    tanh_model = build_model('tanh', num_neurons)

    tanh_history = compile_and_train(tanh_model, x_train, y_train, x_val, y_val)

    if max(tanh_history.history['val_accuracy']) > best_tanh_accuracy:
        best_tanh_accuracy = max(tanh_history.history['val_accuracy'])
        best_tanh_model = tanh_model

tanh_test_loss, tanh_test_accuracy = best_tanh_model.evaluate(x_test, y_test)
print(f"TanH Test Loss: {tanh_test_loss}, TanH Test Accuracy: {tanh_test_accuracy}")
```

```
Epoch 1/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.5122 - accuracy: 0.820
3 - val_loss: 0.4160 - val_accuracy: 0.8463
Epoch 2/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3855 - accuracy: 0.860
5 - val_loss: 0.3750 - val_accuracy: 0.8636
Epoch 3/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3520 - accuracy: 0.871
5 - val_loss: 0.3690 - val_accuracy: 0.8655
Epoch 4/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3302 - accuracy: 0.879
9 - val_loss: 0.3505 - val_accuracy: 0.8738
Epoch 5/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3103 - accuracy: 0.885
9 - val_loss: 0.3568 - val_accuracy: 0.8684
Epoch 6/10
```

```
Epoch 6/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2955 - accuracy: 0.892
1 - val_loss: 0.3243 - val_accuracy: 0.8835
Epoch 7/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2847 - accuracy: 0.895
3 - val_loss: 0.3219 - val_accuracy: 0.8808
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2729 - accuracy: 0.898
2 - val_loss: 0.3274 - val_accuracy: 0.8837
Epoch 9/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2619 - accuracy: 0.902
1 - val_loss: 0.3166 - val_accuracy: 0.8832
Epoch 10/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2542 - accuracy: 0.905
9 - val_loss: 0.3385 - val_accuracy: 0.8782
Epoch 1/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.4967 - accuracy: 0.822
5 - val_loss: 0.4078 - val_accuracy: 0.8510
Epoch 2/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3812 - accuracy: 0.861
2 - val_loss: 0.3722 - val_accuracy: 0.8638
Epoch 3/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3483 - accuracy: 0.872
7 - val_loss: 0.3619 - val_accuracy: 0.8699
Epoch 4/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.3232 - accuracy: 0.880
3 - val_loss: 0.3403 - val_accuracy: 0.8771
Epoch 5/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3038 - accuracy: 0.888
1 - val_loss: 0.3526 - val_accuracy: 0.8683
Epoch 6/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.2871 - accuracy: 0.893
7 - val_loss: 0.3185 - val_accuracy: 0.8850
Epoch 7/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2738 - accuracy: 0.899
3 - val_loss: 0.3163 - val_accuracy: 0.8841
Epoch 8/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2622 - accuracy: 0.902
5 - val_loss: 0.3107 - val_accuracy: 0.8897
Epoch 9/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2535 - accuracy: 0.906
5 - val_loss: 0.3178 - val_accuracy: 0.8852
Epoch 10/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2402 - accuracy: 0.912
8 - val_loss: 0.3296 - val_accuracy: 0.8826
Epoch 1/10
1500/1500 [==============================] - 9s 5ms/step - loss: 0.4908 - accuracy: 0.822
7 - val_loss: 0.4070 - val_accuracy: 0.8518
Epoch 2/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.3765 - accuracy: 0.86
29 - val_loss: 0.3876 - val_accuracy: 0.8577
Epoch 3/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3424 - accuracy: 0.873
3 - val_loss: 0.3524 - val_accuracy: 0.8733
Epoch 4/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.3188 - accuracy: 0.88
28 - val_loss: 0.3296 - val_accuracy: 0.8801
Epoch 5/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2980 - accuracy: 0.88
96 - val_loss: 0.3479 - val_accuracy: 0.8732
Epoch 6/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2809 - accuracy: 0.895
6 - val_loss: 0.3186 - val_accuracy: 0.8840
Epoch 7/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2694 - accuracy: 0.899
6 - val_loss: 0.3131 - val_accuracy: 0.8854
Epoch 8/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2573 - accuracy: 0.90
35 - val_loss: 0.3067 - val_accuracy: 0.8923
Epoch 9/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2485 - accuracy: 0.907
4 - val_loss: 0.3051 - val_accuracy: 0.8878
Epoch 10/10
```

```
Epoch 10/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2400 - accuracy: 0.91
13 - val_loss: 0.3248 - val_accuracy: 0.8819
313/313 [==============================] - 1s 2ms/step - loss: 0.3591 - accuracy: 0.8710
TanH Test Loss: 0.35908907651901245, TanH Test Accuracy: 0.8709999918937683
```

Multiple options for `p` neurons

In [ ]:

```
results = []
# neuron_counts = [32, 64, 128, 256, 512, 1024, 2048]

for neurons in [32, 64, 128, 256, 512, 1024, 2048]:
    history = compile_and_train(
        build_model('tanh', neurons),
        x_train,
        y_train,
        x_val,
        y_val
    )
    results.append(
        (neurons, max(history.history['val_accuracy']), min(history.history['val_loss'])
)
    )
```

```
Epoch 1/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.5490 - accuracy: 0.812
2 - val_loss: 0.4314 - val_accuracy: 0.8442
Epoch 2/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.4025 - accuracy: 0.856
3 - val_loss: 0.3930 - val_accuracy: 0.8585
Epoch 3/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3708 - accuracy: 0.866
1 - val_loss: 0.3863 - val_accuracy: 0.8586
Epoch 4/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3510 - accuracy: 0.872
6 - val_loss: 0.3596 - val_accuracy: 0.8714
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3331 - accuracy: 0.878
8 - val_loss: 0.3536 - val_accuracy: 0.8707
Epoch 6/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3212 - accuracy: 0.882
5 - val_loss: 0.3423 - val_accuracy: 0.8746
Epoch 7/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3107 - accuracy: 0.886
6 - val_loss: 0.3441 - val_accuracy: 0.8773
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3016 - accuracy: 0.889
4 - val_loss: 0.3379 - val_accuracy: 0.8795
Epoch 9/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2949 - accuracy: 0.893
4 - val_loss: 0.3421 - val_accuracy: 0.8748
Epoch 10/10
1500/1500 [==============================] - 4s 2ms/step - loss: 0.2878 - accuracy: 0.895
0 - val_loss: 0.3382 - val_accuracy: 0.8789
Epoch 1/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.5167 - accuracy: 0.815
7 - val_loss: 0.4174 - val_accuracy: 0.8449
Epoch 2/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3895 - accuracy: 0.859
0 - val_loss: 0.3757 - val_accuracy: 0.8607
Epoch 3/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3569 - accuracy: 0.869
3 - val_loss: 0.3664 - val_accuracy: 0.8683
Epoch 4/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3334 - accuracy: 0.878
8 - val_loss: 0.3517 - val_accuracy: 0.8731
Epoch 5/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3131 - accuracy: 0.883
8 - val_loss: 0.3518 - val_accuracy: 0.8693
```

```
Epoch 6/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2983 - accuracy: 0.890
5 - val_loss: 0.3291 - val_accuracy: 0.8802
Epoch 7/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2872 - accuracy: 0.893
8 - val_loss: 0.3214 - val_accuracy: 0.8824
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2764 - accuracy: 0.898
4 - val_loss: 0.3281 - val_accuracy: 0.8834
Epoch 9/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2657 - accuracy: 0.901
2 - val_loss: 0.3187 - val_accuracy: 0.8843
Epoch 10/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.2545 - accuracy: 0.906
4 - val_loss: 0.3284 - val_accuracy: 0.8802
Epoch 1/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.4938 - accuracy: 0.823
4 - val_loss: 0.4112 - val_accuracy: 0.8509
Epoch 2/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3785 - accuracy: 0.863
1 - val_loss: 0.3722 - val_accuracy: 0.8633
Epoch 3/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3439 - accuracy: 0.874
7 - val_loss: 0.3590 - val_accuracy: 0.8697
Epoch 4/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3197 - accuracy: 0.881
6 - val_loss: 0.3350 - val_accuracy: 0.8755
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2988 - accuracy: 0.889
1 - val_loss: 0.3409 - val_accuracy: 0.8767
Epoch 6/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2828 - accuracy: 0.895
9 - val_loss: 0.3130 - val_accuracy: 0.8871
Epoch 7/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2724 - accuracy: 0.898
6 - val_loss: 0.3095 - val_accuracy: 0.8864
Epoch 8/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2592 - accuracy: 0.903
4 - val_loss: 0.3197 - val_accuracy: 0.8857
Epoch 9/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2516 - accuracy: 0.906
2 - val_loss: 0.3158 - val_accuracy: 0.8852
Epoch 10/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2389 - accuracy: 0.910
3 - val_loss: 0.3310 - val_accuracy: 0.8798
Epoch 1/10
1500/1500 [==============================] - 9s 5ms/step - loss: 0.4880 - accuracy: 0.823
2 - val_loss: 0.4128 - val_accuracy: 0.8465
Epoch 2/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.3765 - accuracy: 0.86
20 - val_loss: 0.3840 - val_accuracy: 0.8593
Epoch 3/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.3432 - accuracy: 0.87
29 - val_loss: 0.3613 - val_accuracy: 0.8703
Epoch 4/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3184 - accuracy: 0.883
0 - val_loss: 0.3347 - val_accuracy: 0.8746
Epoch 5/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2965 - accuracy: 0.88
98 - val_loss: 0.3421 - val_accuracy: 0.8758
Epoch 6/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2805 - accuracy: 0.896
3 - val_loss: 0.3148 - val_accuracy: 0.8826
Epoch 7/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2675 - accuracy: 0.90
08 - val_loss: 0.3044 - val_accuracy: 0.8869
Epoch 8/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2574 - accuracy: 0.90
18 - val_loss: 0.3142 - val_accuracy: 0.8866
Epoch 9/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2492 - accuracy: 0.906
2 - val_loss: 0.3053 - val_accuracy: 0.8863
```

```
Epoch 10/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2383 - accuracy: 0.91
06 - val_loss: 0.3466 - val_accuracy: 0.8774
Epoch 1/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.4967 - accuracy: 0.82
05 - val_loss: 0.4198 - val_accuracy: 0.8434
Epoch 2/10
1500/1500 [==============================] - 13s 9ms/step - loss: 0.3842 - accuracy: 0.85
92 - val_loss: 0.3925 - val_accuracy: 0.8523
Epoch 3/10
1500/1500 [==============================] - 13s 9ms/step - loss: 0.3482 - accuracy: 0.87
14 - val_loss: 0.3497 - val_accuracy: 0.8727
Epoch 4/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.3251 - accuracy: 0.87
97 - val_loss: 0.3414 - val_accuracy: 0.8765
Epoch 5/10
1500/1500 [==============================] - 13s 9ms/step - loss: 0.3049 - accuracy: 0.88
63 - val_loss: 0.3402 - val_accuracy: 0.8758
Epoch 6/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2865 - accuracy: 0.89
45 - val_loss: 0.3299 - val_accuracy: 0.8808
Epoch 7/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2736 - accuracy: 0.8
973 - val_loss: 0.3148 - val_accuracy: 0.8815
Epoch 8/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2628 - accuracy: 0.90
02 - val_loss: 0.3193 - val_accuracy: 0.8852
Epoch 9/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2549 - accuracy: 0.90
44 - val_loss: 0.3097 - val_accuracy: 0.8881
Epoch 10/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2453 - accuracy: 0.9
081 - val_loss: 0.3609 - val_accuracy: 0.8727
Epoch 1/10
1500/1500 [==============================] - 23s 15ms/step - loss: 0.5231 - accuracy: 0.8
130 - val_loss: 0.4699 - val_accuracy: 0.8241
Epoch 2/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.4039 - accuracy: 0.8
538 - val_loss: 0.3993 - val_accuracy: 0.8507
Epoch 3/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.3713 - accuracy: 0.8
655 - val_loss: 0.3758 - val_accuracy: 0.8619
Epoch 4/10
1500/1500 [==============================] - 23s 15ms/step - loss: 0.3436 - accuracy: 0.8
734 - val_loss: 0.3656 - val_accuracy: 0.8693
Epoch 5/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.3228 - accuracy: 0.8
800 - val_loss: 0.3612 - val_accuracy: 0.8717
Epoch 6/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.3036 - accuracy: 0.8
882 - val_loss: 0.3537 - val_accuracy: 0.8750
Epoch 7/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.2905 - accuracy: 0.8
931 - val_loss: 0.3248 - val_accuracy: 0.8832
Epoch 8/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.2793 - accuracy: 0.8
958 - val_loss: 0.3273 - val_accuracy: 0.8866
Epoch 9/10
1500/1500 [==============================] - 20s 14ms/step - loss: 0.2709 - accuracy: 0.8
989 - val_loss: 0.3385 - val_accuracy: 0.8793
Epoch 10/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.2570 - accuracy: 0.9
050 - val_loss: 0.3749 - val_accuracy: 0.8730
Epoch 1/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.5612 - accuracy: 0.8
060 - val_loss: 0.5173 - val_accuracy: 0.8084
Epoch 2/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.4342 - accuracy: 0.8
451 - val_loss: 0.3829 - val_accuracy: 0.8602
Epoch 3/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.4027 - accuracy: 0.8
567 - val_loss: 0.4111 - val_accuracy: 0.8566
```

```
Epoch 4/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.3722 - accuracy: 0.8
673 - val_loss: 0.4220 - val_accuracy: 0.8481
Epoch 5/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.3481 - accuracy: 0.8
736 - val_loss: 0.4479 - val_accuracy: 0.8522
Epoch 6/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.3317 - accuracy: 0.8
806 - val_loss: 0.3685 - val_accuracy: 0.8717
Epoch 7/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.3175 - accuracy: 0.8
859 - val_loss: 0.4403 - val_accuracy: 0.8537
Epoch 8/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.3068 - accuracy: 0.8
891 - val_loss: 0.3631 - val_accuracy: 0.8788
Epoch 9/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.3009 - accuracy: 0.8
917 - val_loss: 0.3409 - val_accuracy: 0.8821
Epoch 10/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.2896 - accuracy: 0.8
954 - val_loss: 0.4237 - val_accuracy: 0.8670
```

Performances of `p` neurons' options

In [ ]:

```
neurons, accuracies, losses = zip(*sorted(results))
```

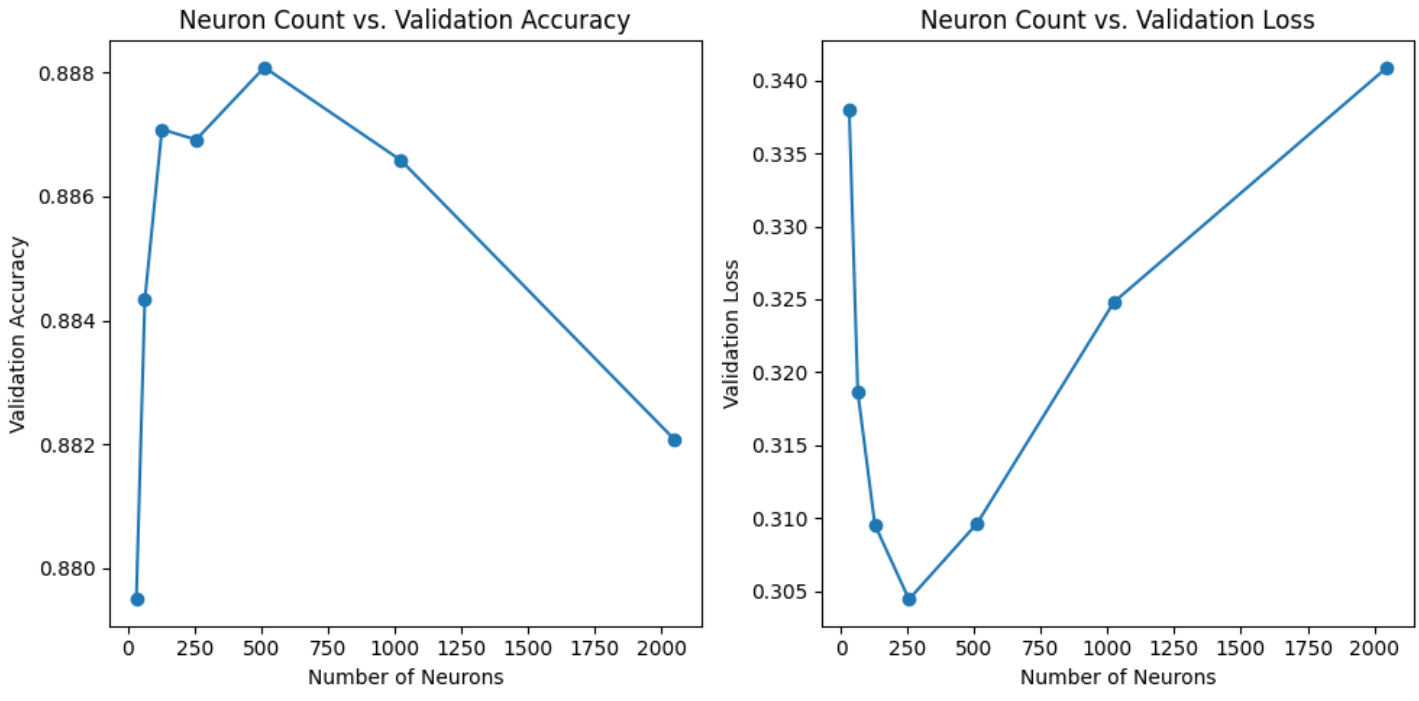
In [ ]:

```
plt.figure(figsize=(10, 5))

plt.subplot(1, 2, 1)
plt.plot(neurons, accuracies, marker='o')
plt.title("Neuron Count vs. Validation Accuracy")
plt.xlabel("Number of Neurons")
plt.ylabel("Validation Accuracy")
# plt.ylim(0.8, 1)

plt.subplot(1, 2, 2)
plt.plot(neurons, losses, marker='o')
plt.title("Neuron Count vs. Validation Loss")
plt.xlabel("Number of Neurons")
plt.ylabel("Validation Loss")

plt.tight_layout()
plt.show()
```



In [ ]:

```
# Sorting results to find the best one
# According to validation accuracy
results.sort(key=lambda x: x[1], reverse=True)
print(f"Best neuron count: {results[0][0]} with Validation Accuracy: {results[0][1]}")
```

```
Best neuron count: 512 with Validation Accuracy: 0.8880833387374878
```

Multi-Layer Perceptron (MLP)

Two-Layer-Dense Model

In [ ]:

```
def build_two_layer_model(size_layer1, size_layer2):
    model = Sequential([
        Flatten(input_shape=(28, 28)),
        Dense(size_layer1, activation='relu'),
        Dense(size_layer2, activation='relu'),
        Dense(10, activation='softmax')
    ])
    return model
```

In [ ]:

```
mlp_layer_sizes = [32, 64, 128, 256, 512]
best_mlp_config = (0, 0)
best_mlp_accuracy = 0
best_mlp_model = None
mlp_results = []

for size1 in mlp_layer_sizes:
    for size2 in mlp_layer_sizes:
        mlp_model = build_two_layer_model(size1, size2)
        mlp_history = compile_and_train(mlp_model, x_train, y_train, x_val, y_val)
        mlp_val_accuracy = max(mlp_history.history['val_accuracy'])
        mlp_results.append(((size1, size2), mlp_val_accuracy))

        if mlp_val_accuracy > best_mlp_accuracy:
            best_mlp_accuracy = mlp_val_accuracy
            best_mlp_model = mlp_model
            best_mlp_config = (size1, size2)
```

```
Epoch 1/10
1500/1500 [==============================] - 6s 3ms/step - loss: 0.5793 - accuracy: 0.795
0 - val_loss: 0.4601 - val_accuracy: 0.8344
Epoch 2/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.4130 - accuracy: 0.853
4 - val_loss: 0.3943 - val_accuracy: 0.8584
Epoch 3/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3779 - accuracy: 0.864
1 - val_loss: 0.3866 - val_accuracy: 0.8628
Epoch 4/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3549 - accuracy: 0.871
7 - val_loss: 0.3603 - val_accuracy: 0.8738
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3366 - accuracy: 0.876
9 - val_loss: 0.3810 - val_accuracy: 0.8660
Epoch 6/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3240 - accuracy: 0.881
8 - val_loss: 0.3443 - val_accuracy: 0.8772
Epoch 7/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3162 - accuracy: 0.884
2 - val_loss: 0.3532 - val_accuracy: 0.8729
Epoch 8/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3061 - accuracy: 0.887
7 - val_loss: 0.3424 - val_accuracy: 0.8802
Epoch 9/10
```

```
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2977 - accuracy: 0.890
4 - val_loss: 0.3430 - val_accuracy: 0.8788
Epoch 10/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2910 - accuracy: 0.893
0 - val_loss: 0.3579 - val_accuracy: 0.8763
Epoch 1/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.5496 - accuracy: 0.806
1 - val_loss: 0.4570 - val_accuracy: 0.8352
Epoch 2/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.4012 - accuracy: 0.856
6 - val_loss: 0.4037 - val_accuracy: 0.8565
Epoch 3/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3677 - accuracy: 0.865
9 - val_loss: 0.3779 - val_accuracy: 0.8664
Epoch 4/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3458 - accuracy: 0.874
6 - val_loss: 0.3512 - val_accuracy: 0.8750
Epoch 5/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3287 - accuracy: 0.877
7 - val_loss: 0.3641 - val_accuracy: 0.8683
Epoch 6/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3123 - accuracy: 0.884
8 - val_loss: 0.3735 - val_accuracy: 0.8646
Epoch 7/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3021 - accuracy: 0.888
6 - val_loss: 0.3343 - val_accuracy: 0.8818
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2913 - accuracy: 0.891
3 - val_loss: 0.3381 - val_accuracy: 0.8804
Epoch 9/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2797 - accuracy: 0.895
0 - val_loss: 0.3401 - val_accuracy: 0.8791
Epoch 10/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2722 - accuracy: 0.898
2 - val_loss: 0.3383 - val_accuracy: 0.8831
Epoch 1/10
1500/1500 [==============================] - 6s 3ms/step - loss: 0.5422 - accuracy: 0.807
1 - val_loss: 0.4485 - val_accuracy: 0.8366
Epoch 2/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3987 - accuracy: 0.856
8 - val_loss: 0.3919 - val_accuracy: 0.8572
Epoch 3/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3640 - accuracy: 0.865
1 - val_loss: 0.3777 - val_accuracy: 0.8633
Epoch 4/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3400 - accuracy: 0.876
0 - val_loss: 0.3568 - val_accuracy: 0.8701
Epoch 5/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3218 - accuracy: 0.880
7 - val_loss: 0.3546 - val_accuracy: 0.8737
Epoch 6/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3057 - accuracy: 0.887
1 - val_loss: 0.3525 - val_accuracy: 0.8702
Epoch 7/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2957 - accuracy: 0.890
3 - val_loss: 0.3334 - val_accuracy: 0.8780
Epoch 8/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2837 - accuracy: 0.894
5 - val_loss: 0.3363 - val_accuracy: 0.8792
Epoch 9/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.2747 - accuracy: 0.897
2 - val_loss: 0.3324 - val_accuracy: 0.8809
Epoch 10/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2669 - accuracy: 0.898
5 - val_loss: 0.3427 - val_accuracy: 0.8793
Epoch 1/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.5356 - accuracy: 0.810
5 - val_loss: 0.4539 - val_accuracy: 0.8254
Epoch 2/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3898 - accuracy: 0.859
1 - val_loss: 0.3817 - val_accuracy: 0.8594
Epoch 3/10
```

```
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3540 - accuracy: 0.869
8 - val_loss: 0.3537 - val_accuracy: 0.8737
Epoch 4/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3306 - accuracy: 0.879
2 - val_loss: 0.3396 - val_accuracy: 0.8775
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3116 - accuracy: 0.884
2 - val_loss: 0.3551 - val_accuracy: 0.8729
Epoch 6/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2968 - accuracy: 0.889
4 - val_loss: 0.3286 - val_accuracy: 0.8808
Epoch 7/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2862 - accuracy: 0.892
7 - val_loss: 0.3307 - val_accuracy: 0.8788
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2758 - accuracy: 0.896
2 - val_loss: 0.3222 - val_accuracy: 0.8863
Epoch 9/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2642 - accuracy: 0.900
3 - val_loss: 0.3285 - val_accuracy: 0.8857
Epoch 10/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2560 - accuracy: 0.903
1 - val_loss: 0.3291 - val_accuracy: 0.8864
Epoch 1/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.5261 - accuracy: 0.810
4 - val_loss: 0.4409 - val_accuracy: 0.8332
Epoch 2/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.3840 - accuracy: 0.859
8 - val_loss: 0.3873 - val_accuracy: 0.8593
Epoch 3/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.3509 - accuracy: 0.869
6 - val_loss: 0.3587 - val_accuracy: 0.8694
Epoch 4/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.3298 - accuracy: 0.878
3 - val_loss: 0.3384 - val_accuracy: 0.8782
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3095 - accuracy: 0.885
0 - val_loss: 0.3626 - val_accuracy: 0.8662
Epoch 6/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2948 - accuracy: 0.889
9 - val_loss: 0.3298 - val_accuracy: 0.8807
Epoch 7/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2844 - accuracy: 0.893
4 - val_loss: 0.3307 - val_accuracy: 0.8808
Epoch 8/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2744 - accuracy: 0.896
5 - val_loss: 0.3281 - val_accuracy: 0.8832
Epoch 9/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2621 - accuracy: 0.900
2 - val_loss: 0.3301 - val_accuracy: 0.8830
Epoch 10/10
1500/1500 [==============================] - 4s 3ms/step - loss: 0.2538 - accuracy: 0.903
9 - val_loss: 0.3324 - val_accuracy: 0.8814
Epoch 1/10
1500/1500 [==============================] - 6s 3ms/step - loss: 0.5526 - accuracy: 0.807
4 - val_loss: 0.4537 - val_accuracy: 0.8363
Epoch 2/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.4072 - accuracy: 0.854
7 - val_loss: 0.3917 - val_accuracy: 0.8608
Epoch 3/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3667 - accuracy: 0.866
9 - val_loss: 0.3936 - val_accuracy: 0.8598
Epoch 4/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3423 - accuracy: 0.876
6 - val_loss: 0.3493 - val_accuracy: 0.8769
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3177 - accuracy: 0.882
8 - val_loss: 0.3616 - val_accuracy: 0.8712
Epoch 6/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3030 - accuracy: 0.888
2 - val_loss: 0.3396 - val_accuracy: 0.8778
Epoch 7/10
```

```
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2918 - accuracy: 0.891
6 - val_loss: 0.3275 - val_accuracy: 0.8838
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2788 - accuracy: 0.895
8 - val_loss: 0.3203 - val_accuracy: 0.8885
Epoch 9/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2697 - accuracy: 0.899
2 - val_loss: 0.3251 - val_accuracy: 0.8856
Epoch 10/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.2598 - accuracy: 0.903
2 - val_loss: 0.3352 - val_accuracy: 0.8836
Epoch 1/10
1500/1500 [==============================] - 6s 3ms/step - loss: 0.5266 - accuracy: 0.814
9 - val_loss: 0.4328 - val_accuracy: 0.8432
Epoch 2/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3885 - accuracy: 0.860
1 - val_loss: 0.3840 - val_accuracy: 0.8573
Epoch 3/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3516 - accuracy: 0.872
4 - val_loss: 0.3642 - val_accuracy: 0.8662
Epoch 4/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3276 - accuracy: 0.880
2 - val_loss: 0.3319 - val_accuracy: 0.8804
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3088 - accuracy: 0.886
4 - val_loss: 0.3439 - val_accuracy: 0.8775
Epoch 6/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2935 - accuracy: 0.892
0 - val_loss: 0.3420 - val_accuracy: 0.8795
Epoch 7/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2822 - accuracy: 0.895
6 - val_loss: 0.3333 - val_accuracy: 0.8781
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2699 - accuracy: 0.898
8 - val_loss: 0.3291 - val_accuracy: 0.8834
Epoch 9/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2612 - accuracy: 0.902
2 - val_loss: 0.3137 - val_accuracy: 0.8894
Epoch 10/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.2493 - accuracy: 0.907
9 - val_loss: 0.3294 - val_accuracy: 0.8824
Epoch 1/10
1500/1500 [==============================] - 6s 3ms/step - loss: 0.5185 - accuracy: 0.816
9 - val_loss: 0.4284 - val_accuracy: 0.8435
Epoch 2/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3781 - accuracy: 0.863
9 - val_loss: 0.4056 - val_accuracy: 0.8525
Epoch 3/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.3447 - accuracy: 0.872
6 - val_loss: 0.3684 - val_accuracy: 0.8683
Epoch 4/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3224 - accuracy: 0.881
0 - val_loss: 0.3380 - val_accuracy: 0.8771
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3038 - accuracy: 0.886
4 - val_loss: 0.3754 - val_accuracy: 0.8654
Epoch 6/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.2896 - accuracy: 0.892
0 - val_loss: 0.3387 - val_accuracy: 0.8771
Epoch 7/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2760 - accuracy: 0.897
5 - val_loss: 0.3179 - val_accuracy: 0.8867
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2655 - accuracy: 0.899
9 - val_loss: 0.3207 - val_accuracy: 0.8847
Epoch 9/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2565 - accuracy: 0.903
6 - val_loss: 0.3238 - val_accuracy: 0.8867
Epoch 10/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2450 - accuracy: 0.907
6 - val_loss: 0.3333 - val_accuracy: 0.8845
Epoch 1/10
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1500/1500 [==============================] - 6s 4ms/step - loss: 0.5129 - accuracy: 0.816
4 - val_loss: 0.4312 - val_accuracy: 0.8378
Epoch 2/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3743 - accuracy: 0.864
3 - val_loss: 0.3722 - val_accuracy: 0.8649
Epoch 3/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.3383 - accuracy: 0.874
4 - val_loss: 0.3644 - val_accuracy: 0.8698
Epoch 4/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.3169 - accuracy: 0.883
3 - val_loss: 0.3291 - val_accuracy: 0.8800
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2978 - accuracy: 0.888
9 - val_loss: 0.3551 - val_accuracy: 0.8689
Epoch 6/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2813 - accuracy: 0.895
1 - val_loss: 0.3285 - val_accuracy: 0.8846
Epoch 7/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2692 - accuracy: 0.898
2 - val_loss: 0.3224 - val_accuracy: 0.8838
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss: 0.2595 - accuracy: 0.902
9 - val_loss: 0.3213 - val_accuracy: 0.8880
Epoch 9/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.2463 - accuracy: 0.906
7 - val_loss: 0.3318 - val_accuracy: 0.8864
Epoch 10/10
1500/1500 [==============================] - 5s 4ms/step - loss: 0.2365 - accuracy: 0.910
5 - val_loss: 0.3479 - val_accuracy: 0.8804
Epoch 1/10
1500/1500 [==============================] - 7s 4ms/step - loss: 0.5064 - accuracy: 0.816
0 - val_loss: 0.4222 - val_accuracy: 0.8415
Epoch 2/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3737 - accuracy: 0.863
0 - val_loss: 0.3758 - val_accuracy: 0.8609
Epoch 3/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.3382 - accuracy: 0.874
5 - val_loss: 0.3580 - val_accuracy: 0.8710
Epoch 4/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3183 - accuracy: 0.880
5 - val_loss: 0.3283 - val_accuracy: 0.8798
Epoch 5/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2983 - accuracy: 0.888
8 - val_loss: 0.3550 - val_accuracy: 0.8715
Epoch 6/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2816 - accuracy: 0.894
2 - val_loss: 0.3215 - val_accuracy: 0.8843
Epoch 7/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2708 - accuracy: 0.897
0 - val_loss: 0.3097 - val_accuracy: 0.8870
Epoch 8/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2591 - accuracy: 0.902
3 - val_loss: 0.3275 - val_accuracy: 0.8833
Epoch 9/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2473 - accuracy: 0.906
1 - val_loss: 0.3344 - val_accuracy: 0.8852
Epoch 10/10
1500/1500 [==============================] - 6s 4ms/step - loss: 0.2366 - accuracy: 0.908
7 - val_loss: 0.3351 - val_accuracy: 0.8862
Epoch 1/10
1500/1500 [==============================] - 9s 5ms/step - loss: 0.5306 - accuracy: 0.812
8 - val_loss: 0.4314 - val_accuracy: 0.8421
Epoch 2/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3840 - accuracy: 0.861
2 - val_loss: 0.3906 - val_accuracy: 0.8547
Epoch 3/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3458 - accuracy: 0.872
8 - val_loss: 0.3581 - val_accuracy: 0.8698
Epoch 4/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3225 - accuracy: 0.881
5 - val_loss: 0.3326 - val_accuracy: 0.8772
Epoch 5/10
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1500/1500 [==============================] - 7s 5ms/step - loss: 0.3034 - accuracy: 0.886
9 - val_loss: 0.3395 - val_accuracy: 0.8765
Epoch 6/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2870 - accuracy: 0.894
4 - val_loss: 0.3327 - val_accuracy: 0.8785
Epoch 7/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2759 - accuracy: 0.896
9 - val_loss: 0.3271 - val_accuracy: 0.8829
Epoch 8/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2649 - accuracy: 0.901
2 - val_loss: 0.3234 - val_accuracy: 0.8850
Epoch 9/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2546 - accuracy: 0.904
8 - val_loss: 0.3251 - val_accuracy: 0.8848
Epoch 10/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2458 - accuracy: 0.907
5 - val_loss: 0.3286 - val_accuracy: 0.8841
Epoch 1/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.5094 - accuracy: 0.819
2 - val_loss: 0.4360 - val_accuracy: 0.8403
Epoch 2/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3778 - accuracy: 0.863
7 - val_loss: 0.3730 - val_accuracy: 0.8656
Epoch 3/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.3389 - accuracy: 0.874
0 - val_loss: 0.3522 - val_accuracy: 0.8716
Epoch 4/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3161 - accuracy: 0.882
8 - val_loss: 0.3274 - val_accuracy: 0.8810
Epoch 5/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2945 - accuracy: 0.890
6 - val_loss: 0.3501 - val_accuracy: 0.8739
Epoch 6/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2813 - accuracy: 0.896
3 - val_loss: 0.3131 - val_accuracy: 0.8862
Epoch 7/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2685 - accuracy: 0.899
0 - val_loss: 0.3222 - val_accuracy: 0.8856
Epoch 8/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2562 - accuracy: 0.903
2 - val_loss: 0.3136 - val_accuracy: 0.8853
Epoch 9/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2474 - accuracy: 0.907
0 - val_loss: 0.3234 - val_accuracy: 0.8881
Epoch 10/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2383 - accuracy: 0.911
0 - val_loss: 0.3222 - val_accuracy: 0.8872
Epoch 1/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.5040 - accuracy: 0.81
99 - val_loss: 0.4311 - val_accuracy: 0.8393
Epoch 2/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3734 - accuracy: 0.863
6 - val_loss: 0.3887 - val_accuracy: 0.8594
Epoch 3/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.3365 - accuracy: 0.87
54 - val_loss: 0.3509 - val_accuracy: 0.8712
Epoch 4/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3144 - accuracy: 0.882
9 - val_loss: 0.3318 - val_accuracy: 0.8779
Epoch 5/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2927 - accuracy: 0.890
8 - val_loss: 0.3499 - val_accuracy: 0.8732
Epoch 6/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2789 - accuracy: 0.897
6 - val_loss: 0.3271 - val_accuracy: 0.8805
Epoch 7/10
1500/1500 [==============================] - 7s 5ms/step - loss: 0.2670 - accuracy: 0.900
3 - val_loss: 0.3196 - val_accuracy: 0.8863
Epoch 8/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2544 - accuracy: 0.904
4 - val_loss: 0.3135 - val_accuracy: 0.8870
Epoch 9/10
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1500/1500 [==============================] - 8s 5ms/step - loss: 0.2438 - accuracy: 0.907
2 - val_loss: 0.3196 - val_accuracy: 0.8895
Epoch 10/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2350 - accuracy: 0.910
3 - val_loss: 0.3239 - val_accuracy: 0.8891
Epoch 1/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.5012 - accuracy: 0.821
0 - val_loss: 0.4268 - val_accuracy: 0.8407
Epoch 2/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.3672 - accuracy: 0.86
52 - val_loss: 0.3720 - val_accuracy: 0.8652
Epoch 3/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.3337 - accuracy: 0.876
6 - val_loss: 0.3435 - val_accuracy: 0.8767
Epoch 4/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.3129 - accuracy: 0.88
43 - val_loss: 0.3299 - val_accuracy: 0.8828
Epoch 5/10
1500/1500 [==============================] - 8s 6ms/step - loss: 0.2903 - accuracy: 0.892
0 - val_loss: 0.3663 - val_accuracy: 0.8668
Epoch 6/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2758 - accuracy: 0.896
9 - val_loss: 0.3156 - val_accuracy: 0.8848
Epoch 7/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2641 - accuracy: 0.901
9 - val_loss: 0.3155 - val_accuracy: 0.8873
Epoch 8/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2509 - accuracy: 0.905
7 - val_loss: 0.3150 - val_accuracy: 0.8884
Epoch 9/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2407 - accuracy: 0.910
5 - val_loss: 0.3141 - val_accuracy: 0.8888
Epoch 10/10
1500/1500 [==============================] - 8s 5ms/step - loss: 0.2304 - accuracy: 0.912
0 - val_loss: 0.3203 - val_accuracy: 0.8868
Epoch 1/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.4914 - accuracy: 0.82
27 - val_loss: 0.4218 - val_accuracy: 0.8418
Epoch 2/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3661 - accuracy: 0.865
8 - val_loss: 0.3645 - val_accuracy: 0.8668
Epoch 3/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.3313 - accuracy: 0.87
62 - val_loss: 0.3489 - val_accuracy: 0.8738
Epoch 4/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3114 - accuracy: 0.885
8 - val_loss: 0.3205 - val_accuracy: 0.8837
Epoch 5/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2920 - accuracy: 0.891
2 - val_loss: 0.3828 - val_accuracy: 0.8648
Epoch 6/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2738 - accuracy: 0.89
76 - val_loss: 0.3370 - val_accuracy: 0.8787
Epoch 7/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.2615 - accuracy: 0.900
9 - val_loss: 0.3205 - val_accuracy: 0.8879
Epoch 8/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2483 - accuracy: 0.90
47 - val_loss: 0.3379 - val_accuracy: 0.8864
Epoch 9/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2354 - accuracy: 0.90
94 - val_loss: 0.3319 - val_accuracy: 0.8873
Epoch 10/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2260 - accuracy: 0.91
38 - val_loss: 0.3261 - val_accuracy: 0.8879
Epoch 1/10
1500/1500 [==============================] - 12s 7ms/step - loss: 0.5138 - accuracy: 0.81
77 - val_loss: 0.4326 - val_accuracy: 0.8404
Epoch 2/10
1500/1500 [==============================] - 9s 6ms/step - loss: 0.3759 - accuracy: 0.861
7 - val_loss: 0.3894 - val_accuracy: 0.8570
Epoch 3/10
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1500/1500 [==============================] - 10s 7ms/step - loss: 0.3376 - accuracy: 0.87
49 - val_loss: 0.3458 - val_accuracy: 0.8742
Epoch 4/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.3162 - accuracy: 0.88
38 - val_loss: 0.3316 - val_accuracy: 0.8796
Epoch 5/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2943 - accuracy: 0.89
10 - val_loss: 0.3383 - val_accuracy: 0.8776
Epoch 6/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2792 - accuracy: 0.89
54 - val_loss: 0.3233 - val_accuracy: 0.8852
Epoch 7/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2676 - accuracy: 0.90
06 - val_loss: 0.3067 - val_accuracy: 0.8885
Epoch 8/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.2538 - accuracy: 0.90
30 - val_loss: 0.3239 - val_accuracy: 0.8884
Epoch 9/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2416 - accuracy: 0.90
93 - val_loss: 0.3256 - val_accuracy: 0.8863
Epoch 10/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2340 - accuracy: 0.91
24 - val_loss: 0.3491 - val_accuracy: 0.8827
Epoch 1/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.5013 - accuracy: 0.82
09 - val_loss: 0.4222 - val_accuracy: 0.8468
Epoch 2/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.3724 - accuracy: 0.86
36 - val_loss: 0.3875 - val_accuracy: 0.8564
Epoch 3/10
1500/1500 [==============================] - 10s 7ms/step - loss: 0.3356 - accuracy: 0.87
57 - val_loss: 0.3587 - val_accuracy: 0.8731
Epoch 4/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.3134 - accuracy: 0.88
45 - val_loss: 0.3301 - val_accuracy: 0.8767
Epoch 5/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2950 - accuracy: 0.89
05 - val_loss: 0.3500 - val_accuracy: 0.8730
Epoch 6/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2762 - accuracy: 0.89
75 - val_loss: 0.3232 - val_accuracy: 0.8827
Epoch 7/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2666 - accuracy: 0.90
04 - val_loss: 0.3083 - val_accuracy: 0.8879
Epoch 8/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2533 - accuracy: 0.90
34 - val_loss: 0.3080 - val_accuracy: 0.8898
Epoch 9/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2415 - accuracy: 0.90
88 - val_loss: 0.3149 - val_accuracy: 0.8880
Epoch 10/10
1500/1500 [==============================] - 10s 6ms/step - loss: 0.2320 - accuracy: 0.91
13 - val_loss: 0.3339 - val_accuracy: 0.8868
Epoch 1/10
1500/1500 [==============================] - 13s 8ms/step - loss: 0.4964 - accuracy: 0.82
13 - val_loss: 0.4173 - val_accuracy: 0.8417
Epoch 2/10
1500/1500 [==============================] - 11s 8ms/step - loss: 0.3673 - accuracy: 0.86
60 - val_loss: 0.3788 - val_accuracy: 0.8619
Epoch 3/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.3294 - accuracy: 0.87
83 - val_loss: 0.3508 - val_accuracy: 0.8753
Epoch 4/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.3081 - accuracy: 0.88
52 - val_loss: 0.3361 - val_accuracy: 0.8792
Epoch 5/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2851 - accuracy: 0.89
37 - val_loss: 0.3461 - val_accuracy: 0.8733
Epoch 6/10
1500/1500 [==============================] - 11s 8ms/step - loss: 0.2705 - accuracy: 0.89
79 - val_loss: 0.3214 - val_accuracy: 0.8832
Epoch 7/10
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1500/1500 [==============================] - 10s 7ms/step - loss: 0.2591 - accuracy: 0.90
28 - val_loss: 0.3169 - val_accuracy: 0.8878
Epoch 8/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2475 - accuracy: 0.90
66 - val_loss: 0.3318 - val_accuracy: 0.8858
Epoch 9/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2365 - accuracy: 0.91
24 - val_loss: 0.3160 - val_accuracy: 0.8852
Epoch 10/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2262 - accuracy: 0.91
39 - val_loss: 0.3443 - val_accuracy: 0.8837
Epoch 1/10
1500/1500 [==============================] - 13s 8ms/step - loss: 0.4905 - accuracy: 0.82
27 - val_loss: 0.4196 - val_accuracy: 0.8453
Epoch 2/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.3647 - accuracy: 0.86
67 - val_loss: 0.3684 - val_accuracy: 0.8668
Epoch 3/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.3291 - accuracy: 0.87
78 - val_loss: 0.3395 - val_accuracy: 0.8785
Epoch 4/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.3080 - accuracy: 0.88
55 - val_loss: 0.3254 - val_accuracy: 0.8788
Epoch 5/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2862 - accuracy: 0.89
35 - val_loss: 0.3429 - val_accuracy: 0.8777
Epoch 6/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2718 - accuracy: 0.89
76 - val_loss: 0.3223 - val_accuracy: 0.8850
Epoch 7/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2588 - accuracy: 0.90
24 - val_loss: 0.3056 - val_accuracy: 0.8888
Epoch 8/10
1500/1500 [==============================] - 11s 7ms/step - loss: 0.2453 - accuracy: 0.90
55 - val_loss: 0.3265 - val_accuracy: 0.8835
Epoch 9/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2326 - accuracy: 0.91
15 - val_loss: 0.3237 - val_accuracy: 0.8879
Epoch 10/10
1500/1500 [==============================] - 12s 8ms/step - loss: 0.2244 - accuracy: 0.91
49 - val_loss: 0.3425 - val_accuracy: 0.8874
Epoch 1/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.4830 - accuracy: 0.82
45 - val_loss: 0.4121 - val_accuracy: 0.8475
Epoch 2/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.3656 - accuracy: 0.86
61 - val_loss: 0.3652 - val_accuracy: 0.8692
Epoch 3/10
1500/1500 [==============================] - 13s 9ms/step - loss: 0.3292 - accuracy: 0.87
66 - val_loss: 0.3652 - val_accuracy: 0.8717
Epoch 4/10
1500/1500 [==============================] - 13s 8ms/step - loss: 0.3067 - accuracy: 0.88
63 - val_loss: 0.3321 - val_accuracy: 0.8816
Epoch 5/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2865 - accuracy: 0.89
30 - val_loss: 0.3612 - val_accuracy: 0.8707
Epoch 6/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2710 - accuracy: 0.8
980 - val_loss: 0.3367 - val_accuracy: 0.8790
Epoch 7/10
1500/1500 [==============================] - 13s 9ms/step - loss: 0.2590 - accuracy: 0.90
24 - val_loss: 0.3046 - val_accuracy: 0.8911
Epoch 8/10
1500/1500 [==============================] - 13s 9ms/step - loss: 0.2467 - accuracy: 0.90
56 - val_loss: 0.3403 - val_accuracy: 0.8848
Epoch 9/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2349 - accuracy: 0.91
05 - val_loss: 0.3142 - val_accuracy: 0.8882
Epoch 10/10
1500/1500 [==============================] - 13s 9ms/step - loss: 0.2221 - accuracy: 0.91
53 - val_loss: 0.3499 - val_accuracy: 0.8853
Epoch 1/10
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1500/1500 [==============================] - 15s 10ms/step - loss: 0.5080 - accuracy: 0.8
193 - val_loss: 0.4135 - val_accuracy: 0.8468
Epoch 2/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.3742 - accuracy: 0.86
37 - val_loss: 0.4001 - val_accuracy: 0.8518
Epoch 3/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.3363 - accuracy: 0.87
56 - val_loss: 0.3615 - val_accuracy: 0.8712
Epoch 4/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.3131 - accuracy: 0.88
47 - val_loss: 0.3402 - val_accuracy: 0.8779
Epoch 5/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2926 - accuracy: 0.8
915 - val_loss: 0.3432 - val_accuracy: 0.8755
Epoch 6/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2759 - accuracy: 0.89
76 - val_loss: 0.3116 - val_accuracy: 0.8872
Epoch 7/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2628 - accuracy: 0.9
021 - val_loss: 0.3062 - val_accuracy: 0.8916
Epoch 8/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2514 - accuracy: 0.9
044 - val_loss: 0.3147 - val_accuracy: 0.8882
Epoch 9/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2393 - accuracy: 0.91
01 - val_loss: 0.3153 - val_accuracy: 0.8882
Epoch 10/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2274 - accuracy: 0.9
145 - val_loss: 0.3404 - val_accuracy: 0.8847
Epoch 1/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.4918 - accuracy: 0.8
233 - val_loss: 0.4409 - val_accuracy: 0.8367
Epoch 2/10
1500/1500 [==============================] - 14s 10ms/step - loss: 0.3683 - accuracy: 0.8
646 - val_loss: 0.3760 - val_accuracy: 0.8612
Epoch 3/10
1500/1500 [==============================] - 14s 10ms/step - loss: 0.3314 - accuracy: 0.8
765 - val_loss: 0.3565 - val_accuracy: 0.8749
Epoch 4/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.3092 - accuracy: 0.8
854 - val_loss: 0.3171 - val_accuracy: 0.8838
Epoch 5/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2873 - accuracy: 0.8
929 - val_loss: 0.3427 - val_accuracy: 0.8788
Epoch 6/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2726 - accuracy: 0.89
94 - val_loss: 0.3138 - val_accuracy: 0.8873
Epoch 7/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2605 - accuracy: 0.9
030 - val_loss: 0.3085 - val_accuracy: 0.8907
Epoch 8/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2475 - accuracy: 0.9
059 - val_loss: 0.3303 - val_accuracy: 0.8854
Epoch 9/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.2349 - accuracy: 0.9
114 - val_loss: 0.3123 - val_accuracy: 0.8918
Epoch 10/10
1500/1500 [==============================] - 14s 10ms/step - loss: 0.2257 - accuracy: 0.9
145 - val_loss: 0.3384 - val_accuracy: 0.8843
Epoch 1/10
1500/1500 [==============================] - 16s 10ms/step - loss: 0.4902 - accuracy: 0.8
230 - val_loss: 0.4368 - val_accuracy: 0.8337
Epoch 2/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.3666 - accuracy: 0.8
660 - val_loss: 0.4058 - val_accuracy: 0.8504
Epoch 3/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.3298 - accuracy: 0.8
778 - val_loss: 0.3352 - val_accuracy: 0.8802
Epoch 4/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.3064 - accuracy: 0.8
857 - val_loss: 0.3241 - val_accuracy: 0.8831
Epoch 5/10
```

```
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2850 - accuracy: 0.8
938 - val_loss: 0.3494 - val_accuracy: 0.8737
Epoch 6/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2680 - accuracy: 0.9
003 - val_loss: 0.3185 - val_accuracy: 0.8836
Epoch 7/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2567 - accuracy: 0.9
024 - val_loss: 0.3068 - val_accuracy: 0.8888
Epoch 8/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2439 - accuracy: 0.9
068 - val_loss: 0.3313 - val_accuracy: 0.8843
Epoch 9/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2329 - accuracy: 0.9
125 - val_loss: 0.3231 - val_accuracy: 0.8887
Epoch 10/10
1500/1500 [==============================] - 15s 10ms/step - loss: 0.2225 - accuracy: 0.9
160 - val_loss: 0.3399 - val_accuracy: 0.8873
Epoch 1/10
1500/1500 [==============================] - 18s 12ms/step - loss: 0.4850 - accuracy: 0.8
249 - val_loss: 0.4104 - val_accuracy: 0.8480
Epoch 2/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.3645 - accuracy: 0.8
668 - val_loss: 0.3716 - val_accuracy: 0.8647
Epoch 3/10
1500/1500 [==============================] - 18s 12ms/step - loss: 0.3293 - accuracy: 0.8
767 - val_loss: 0.3428 - val_accuracy: 0.8796
Epoch 4/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.3050 - accuracy: 0.8
853 - val_loss: 0.3225 - val_accuracy: 0.8815
Epoch 5/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.2848 - accuracy: 0.8
934 - val_loss: 0.3351 - val_accuracy: 0.8766
Epoch 6/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.2673 - accuracy: 0.9
001 - val_loss: 0.3181 - val_accuracy: 0.8880
Epoch 7/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.2591 - accuracy: 0.9
027 - val_loss: 0.3203 - val_accuracy: 0.8852
Epoch 8/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.2441 - accuracy: 0.9
064 - val_loss: 0.3266 - val_accuracy: 0.8873
Epoch 9/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.2326 - accuracy: 0.9
116 - val_loss: 0.3153 - val_accuracy: 0.8899
Epoch 10/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.2244 - accuracy: 0.9
145 - val_loss: 0.3281 - val_accuracy: 0.8872
Epoch 1/10
1500/1500 [==============================] - 21s 13ms/step - loss: 0.4821 - accuracy: 0.8
254 - val_loss: 0.4056 - val_accuracy: 0.8506
Epoch 2/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.3623 - accuracy: 0.8
677 - val_loss: 0.3714 - val_accuracy: 0.8655
Epoch 3/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.3283 - accuracy: 0.8
776 - val_loss: 0.3392 - val_accuracy: 0.8770
Epoch 4/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.3042 - accuracy: 0.8
871 - val_loss: 0.3208 - val_accuracy: 0.8821
Epoch 5/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.2840 - accuracy: 0.8
939 - val_loss: 0.3349 - val_accuracy: 0.8770
Epoch 6/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.2668 - accuracy: 0.9
001 - val_loss: 0.3053 - val_accuracy: 0.8903
Epoch 7/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.2543 - accuracy: 0.9
038 - val_loss: 0.3149 - val_accuracy: 0.8878
Epoch 8/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.2448 - accuracy: 0.9
056 - val_loss: 0.3246 - val_accuracy: 0.8880
Epoch 9/10
```

```
1500/1500 [==============================] - 20s 13ms/step - loss: 0.2283 - accuracy: 0.9
131 - val_loss: 0.3255 - val_accuracy: 0.8896
Epoch 10/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.2179 - accuracy: 0.9
172 - val_loss: 0.3416 - val_accuracy: 0.8883
```

In [ ]:

```
# Sorting the results to find the best one
best_mlp_config, best_mlp_accuracy = max(mlp_results, key=lambda x: x[1])
print(f"Best Configuration: {best_mlp_config} with Validation Accuracy: {best_mlp_accurac
y}")
```

```
Best Configuration: (512, 64) with Validation Accuracy: 0.8918333053588867
```

In [ ]:

```
# Final evaluation on the test set
best_mlp_model = build_two_layer_model(*best_mlp_config)
compile_and_train(best_mlp_model, x_train, y_train, x_val, y_val)
mlp_test_loss, mlp_test_accuracy = best_mlp_model.evaluate(x_test, y_test)
print(f"MLP Test Loss: {mlp_test_loss}, MLP Test Accuracy: {mlp_test_accuracy}")
```

```
Epoch 1/10
1500/1500 [==============================] - 15s 9ms/step - loss: 0.4969 - accuracy: 0.82
29 - val_loss: 0.4068 - val_accuracy: 0.8503
Epoch 2/10
1500/1500 [==============================] - 14s 10ms/step - loss: 0.3697 - accuracy: 0.8
658 - val_loss: 0.3871 - val_accuracy: 0.8584
Epoch 3/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.3324 - accuracy: 0.87
68 - val_loss: 0.3451 - val_accuracy: 0.8765
Epoch 4/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.3107 - accuracy: 0.88
54 - val_loss: 0.3472 - val_accuracy: 0.8775
Epoch 5/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2886 - accuracy: 0.89
31 - val_loss: 0.3531 - val_accuracy: 0.8723
Epoch 6/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2720 - accuracy: 0.89
88 - val_loss: 0.3120 - val_accuracy: 0.8861
Epoch 7/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2591 - accuracy: 0.90
22 - val_loss: 0.3054 - val_accuracy: 0.8910
Epoch 8/10
1500/1500 [==============================] - 14s 9ms/step - loss: 0.2452 - accuracy: 0.90
76 - val_loss: 0.3188 - val_accuracy: 0.8873
Epoch 9/10
1500/1500 [==============================] - 14s 10ms/step - loss: 0.2356 - accuracy: 0.9
110 - val_loss: 0.3107 - val_accuracy: 0.8897
Epoch 10/10
1500/1500 [==============================] - 14s 10ms/step - loss: 0.2248 - accuracy: 0.9
155 - val_loss: 0.3302 - val_accuracy: 0.8894
313/313 [==============================] - 1s 3ms/step - loss: 0.3580 - accuracy: 0.8812
MLP Test Loss: 0.3580497205257416, MLP Test Accuracy: 0.8812000155448914
```

In [ ]:

```
accuracy_matrix = np.zeros((len(mlp_layer_sizes), len(mlp_layer_sizes)))
```

In [ ]:

```
# Populate the matrix with your results
for (size1, size2), accuracy in mlp_results:
    i = mlp_layer_sizes.index(size1)
    j = mlp_layer_sizes.index(size2)
    accuracy_matrix[i][j] = accuracy
```

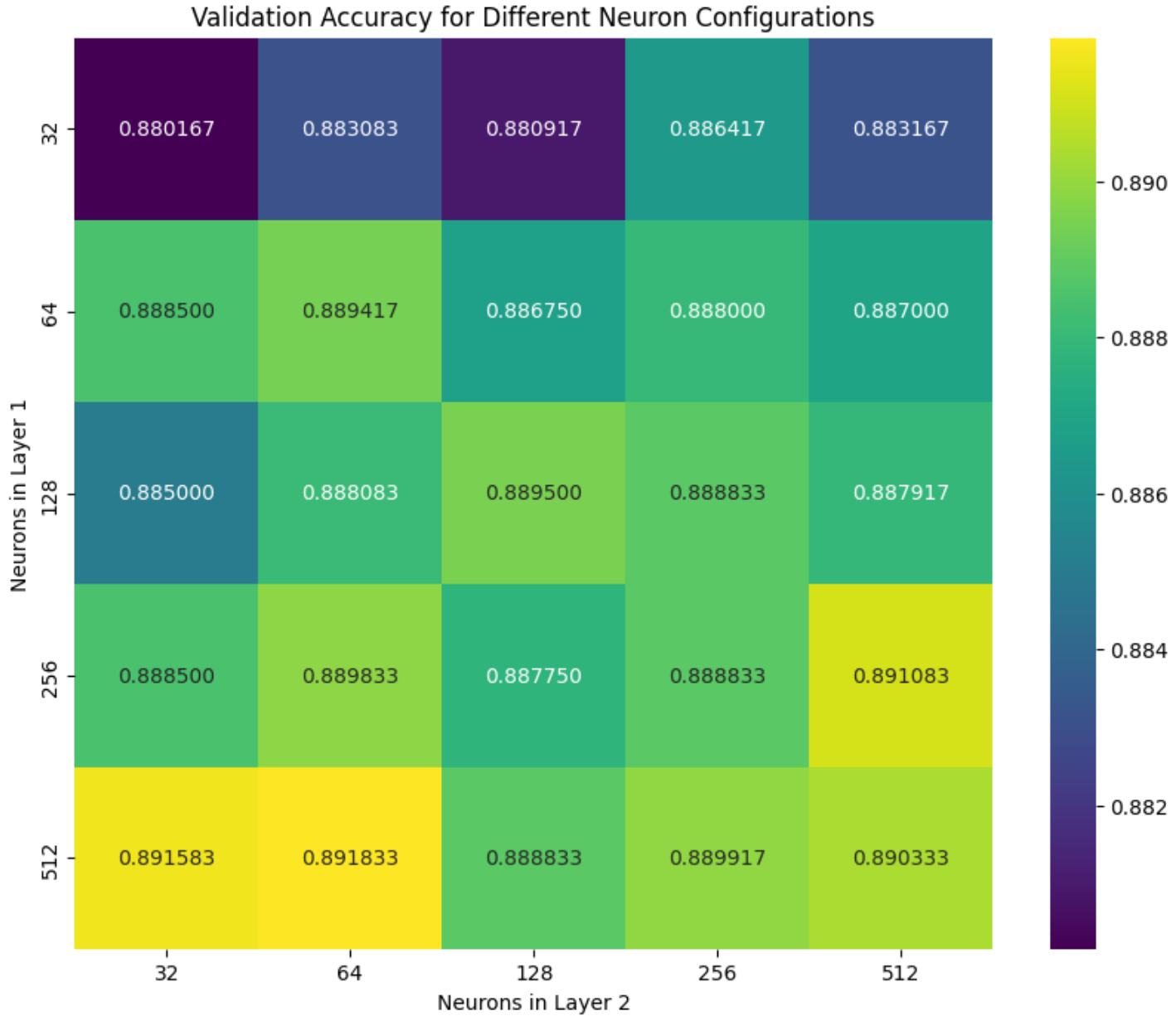
In [ ]:

```
# Create the heatmap
```

```
plt.figure(figsize=(10, 8))

sns.heatmap(accuracy_matrix,
    annot=True,
    fmt=".6f",
    xticklabels=mlp_layer_sizes,
    yticklabels=mlp_layer_sizes,
    cmap="viridis"
)

plt.title("Validation Accuracy for Different Neuron Configurations")
plt.xlabel("Neurons in Layer 2")
plt.ylabel("Neurons in Layer 1")
plt.show()
```



Convolutional Neural Network (CNN)

Two-Layer-Convolutional Model

In [ ]:

```
def build_cnn_model(filters1, kernel_size1, filters2, kernel_size2, stride1=2, stride2=2
):
    model = Sequential([
        Conv2D(filters1, kernel_size1, strides=stride1, activation='relu', input_shape=(
28, 28, 1)),
        Conv2D(filters2, kernel_size2, strides=stride2, activation='relu'),
        Flatten(),
```

```
        Dense(128, activation='relu'),
        Dense(10, activation='softmax')
    ])
    return model
```

In [ ]:

```
# Initialize an empty list to store the results
cnn_results = []

# Define ranges for hyperparameters
kernel_sizes = [(3, 3), (5, 5)]
filter_sizes = [32, 64, 128]

# Grid search
best_cnn_model = None
best_cnn_accuracy = 0
for filters1 in filter_sizes:
    for kernel_size1 in kernel_sizes:
        for filters2 in filter_sizes:
            for kernel_size2 in kernel_sizes:
                cnn_model = build_cnn_model(filters1, kernel_size1, filters2, kernel_siz
e2)
                cnn_history = compile_and_train(cnn_model, x_train, y_train, x_val, y_va
l)
                cnn_results.append((filters1, kernel_size1, filters2, kernel_size2, max(
cnn_history.history['val_accuracy'])))

                if max(cnn_history.history['val_accuracy']) > best_cnn_accuracy:
                    best_cnn_model = max(cnn_history.history['val_accuracy'])
                    best_cnn_model = cnn_model
```

```
Epoch 1/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.4844 - accuracy: 0.8
268 - val_loss: 0.3693 - val_accuracy: 0.8655
Epoch 2/10
1500/1500 [==============================] - 16s 10ms/step - loss: 0.3288 - accuracy: 0.8
806 - val_loss: 0.3105 - val_accuracy: 0.8878
Epoch 3/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.2773 - accuracy: 0.8
973 - val_loss: 0.2830 - val_accuracy: 0.8960
Epoch 4/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.2439 - accuracy: 0.9
099 - val_loss: 0.2794 - val_accuracy: 0.8970
Epoch 5/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.2139 - accuracy: 0.9
199 - val_loss: 0.2703 - val_accuracy: 0.9034
Epoch 6/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.1915 - accuracy: 0.9
280 - val_loss: 0.2699 - val_accuracy: 0.9029
Epoch 7/10
1500/1500 [==============================] - 17s 12ms/step - loss: 0.1687 - accuracy: 0.9
366 - val_loss: 0.2593 - val_accuracy: 0.9084
Epoch 8/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.1488 - accuracy: 0.9
442 - val_loss: 0.2779 - val_accuracy: 0.9084
Epoch 9/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.1293 - accuracy: 0.9
522 - val_loss: 0.2879 - val_accuracy: 0.9059
Epoch 10/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.1133 - accuracy: 0.9
575 - val_loss: 0.3052 - val_accuracy: 0.9015
Epoch 1/10
1500/1500 [==============================] - 19s 12ms/step - loss: 0.4805 - accuracy: 0.8
272 - val_loss: 0.3654 - val_accuracy: 0.8663
Epoch 2/10
1500/1500 [==============================] - 18s 12ms/step - loss: 0.3157 - accuracy: 0.8
838 - val_loss: 0.3041 - val_accuracy: 0.8886
Epoch 3/10
1500/1500 [==============================] - 20s 14ms/step - loss: 0.2703 - accuracy: 0.9
004 - val_loss: 0.2785 - val_accuracy: 0.8967
Epoch 4/10
```

```
1500/1500 [==============================] - 18s 12ms/step - loss: 0.2379 - accuracy: 0.9
120 - val_loss: 0.2740 - val_accuracy: 0.8986
Epoch 5/10
1500/1500 [==============================] - 18s 12ms/step - loss: 0.2115 - accuracy: 0.9
215 - val_loss: 0.2774 - val_accuracy: 0.8967
Epoch 6/10
1500/1500 [==============================] - 18s 12ms/step - loss: 0.1890 - accuracy: 0.9
281 - val_loss: 0.2789 - val_accuracy: 0.8992
Epoch 7/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.1688 - accuracy: 0.9
373 - val_loss: 0.2583 - val_accuracy: 0.9100
Epoch 8/10
1500/1500 [==============================] - 19s 12ms/step - loss: 0.1496 - accuracy: 0.9
442 - val_loss: 0.2722 - val_accuracy: 0.9085
Epoch 9/10
1500/1500 [==============================] - 18s 12ms/step - loss: 0.1324 - accuracy: 0.9
510 - val_loss: 0.2943 - val_accuracy: 0.9020
Epoch 10/10
1500/1500 [==============================] - 18s 12ms/step - loss: 0.1155 - accuracy: 0.9
574 - val_loss: 0.2894 - val_accuracy: 0.9046
Epoch 1/10
1500/1500 [==============================] - 23s 14ms/step - loss: 0.4558 - accuracy: 0.8
349 - val_loss: 0.3570 - val_accuracy: 0.8670
Epoch 2/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.3025 - accuracy: 0.8
881 - val_loss: 0.2987 - val_accuracy: 0.8903
Epoch 3/10
1500/1500 [==============================] - 23s 15ms/step - loss: 0.2541 - accuracy: 0.9
060 - val_loss: 0.2676 - val_accuracy: 0.9025
Epoch 4/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.2178 - accuracy: 0.9
187 - val_loss: 0.2580 - val_accuracy: 0.9075
Epoch 5/10
1500/1500 [==============================] - 22s 14ms/step - loss: 0.1858 - accuracy: 0.9
306 - val_loss: 0.2678 - val_accuracy: 0.9028
Epoch 6/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.1600 - accuracy: 0.9
401 - val_loss: 0.2617 - val_accuracy: 0.9115
Epoch 7/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.1335 - accuracy: 0.9
503 - val_loss: 0.2792 - val_accuracy: 0.9080
Epoch 8/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.1122 - accuracy: 0.9
587 - val_loss: 0.3049 - val_accuracy: 0.9063
Epoch 9/10
1500/1500 [==============================] - 23s 16ms/step - loss: 0.0922 - accuracy: 0.9
660 - val_loss: 0.3170 - val_accuracy: 0.9051
Epoch 10/10
1500/1500 [==============================] - 20s 14ms/step - loss: 0.0750 - accuracy: 0.9
722 - val_loss: 0.3442 - val_accuracy: 0.9072
Epoch 1/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.4668 - accuracy: 0.8
308 - val_loss: 0.3554 - val_accuracy: 0.8710
Epoch 2/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.3071 - accuracy: 0.8
862 - val_loss: 0.3017 - val_accuracy: 0.8883
Epoch 3/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.2571 - accuracy: 0.9
045 - val_loss: 0.2732 - val_accuracy: 0.9005
Epoch 4/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.2211 - accuracy: 0.9
173 - val_loss: 0.2661 - val_accuracy: 0.9032
Epoch 5/10
1500/1500 [==============================] - 25s 17ms/step - loss: 0.1882 - accuracy: 0.9
303 - val_loss: 0.2648 - val_accuracy: 0.9049
Epoch 6/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.1622 - accuracy: 0.9
399 - val_loss: 0.2699 - val_accuracy: 0.9069
Epoch 7/10
1500/1500 [==============================] - 25s 17ms/step - loss: 0.1373 - accuracy: 0.9
501 - val_loss: 0.2759 - val_accuracy: 0.9069
Epoch 8/10
```

```
1500/1500 [==============================] - 25s 17ms/step - loss: 0.1156 - accuracy: 0.9
579 - val_loss: 0.2923 - val_accuracy: 0.9078
Epoch 9/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.0977 - accuracy: 0.9
631 - val_loss: 0.3299 - val_accuracy: 0.9026
Epoch 10/10
1500/1500 [==============================] - 28s 18ms/step - loss: 0.0803 - accuracy: 0.9
701 - val_loss: 0.3478 - val_accuracy: 0.9049
Epoch 1/10
1500/1500 [==============================] - 34s 22ms/step - loss: 0.4446 - accuracy: 0.8
413 - val_loss: 0.3393 - val_accuracy: 0.8758
Epoch 2/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.2921 - accuracy: 0.8
934 - val_loss: 0.2896 - val_accuracy: 0.8949
Epoch 3/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2423 - accuracy: 0.9
114 - val_loss: 0.2587 - val_accuracy: 0.9069
Epoch 4/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2039 - accuracy: 0.9
251 - val_loss: 0.2618 - val_accuracy: 0.9043
Epoch 5/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.1698 - accuracy: 0.9
361 - val_loss: 0.2601 - val_accuracy: 0.9086
Epoch 6/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.1406 - accuracy: 0.9
473 - val_loss: 0.2643 - val_accuracy: 0.9068
Epoch 7/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.1124 - accuracy: 0.9
587 - val_loss: 0.2725 - val_accuracy: 0.9118
Epoch 8/10
1500/1500 [==============================] - 32s 22ms/step - loss: 0.0883 - accuracy: 0.9
669 - val_loss: 0.3228 - val_accuracy: 0.9072
Epoch 9/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.0708 - accuracy: 0.9
740 - val_loss: 0.3391 - val_accuracy: 0.9081
Epoch 10/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.0585 - accuracy: 0.9
786 - val_loss: 0.3526 - val_accuracy: 0.9078
Epoch 1/10
1500/1500 [==============================] - 41s 26ms/step - loss: 0.4456 - accuracy: 0.8
375 - val_loss: 0.3472 - val_accuracy: 0.8682
Epoch 2/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.2922 - accuracy: 0.8
928 - val_loss: 0.2869 - val_accuracy: 0.8921
Epoch 3/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.2405 - accuracy: 0.9
109 - val_loss: 0.2632 - val_accuracy: 0.9021
Epoch 4/10
1500/1500 [==============================] - 40s 26ms/step - loss: 0.2002 - accuracy: 0.9
262 - val_loss: 0.2649 - val_accuracy: 0.9024
Epoch 5/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.1656 - accuracy: 0.9
387 - val_loss: 0.2618 - val_accuracy: 0.9056
Epoch 6/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.1369 - accuracy: 0.9
484 - val_loss: 0.2692 - val_accuracy: 0.9072
Epoch 7/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.1106 - accuracy: 0.9
595 - val_loss: 0.2908 - val_accuracy: 0.9078
Epoch 8/10
1500/1500 [==============================] - 40s 26ms/step - loss: 0.0911 - accuracy: 0.9
664 - val_loss: 0.3299 - val_accuracy: 0.9055
Epoch 9/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.0758 - accuracy: 0.9
714 - val_loss: 0.3565 - val_accuracy: 0.9039
Epoch 10/10
1500/1500 [==============================] - 38s 26ms/step - loss: 0.0591 - accuracy: 0.9
774 - val_loss: 0.4110 - val_accuracy: 0.9038
Epoch 1/10
1500/1500 [==============================] - 18s 11ms/step - loss: 0.5286 - accuracy: 0.8
077 - val_loss: 0.4031 - val_accuracy: 0.8535
Epoch 2/10
```

```
1500/1500 [==============================] - 18s 12ms/step - loss: 0.3618 - accuracy: 0.8
658 - val_loss: 0.3440 - val_accuracy: 0.8749
Epoch 3/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.3125 - accuracy: 0.8
833 - val_loss: 0.3279 - val_accuracy: 0.8817
Epoch 4/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.2796 - accuracy: 0.8
951 - val_loss: 0.3197 - val_accuracy: 0.8853
Epoch 5/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.2532 - accuracy: 0.9
055 - val_loss: 0.3155 - val_accuracy: 0.8870
Epoch 6/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.2311 - accuracy: 0.9
135 - val_loss: 0.3040 - val_accuracy: 0.8903
Epoch 7/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.2103 - accuracy: 0.9
220 - val_loss: 0.3032 - val_accuracy: 0.8930
Epoch 8/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.1911 - accuracy: 0.9
294 - val_loss: 0.3087 - val_accuracy: 0.8953
Epoch 9/10
1500/1500 [==============================] - 16s 11ms/step - loss: 0.1737 - accuracy: 0.9
344 - val_loss: 0.3090 - val_accuracy: 0.8969
Epoch 10/10
1500/1500 [==============================] - 17s 11ms/step - loss: 0.1561 - accuracy: 0.9
411 - val_loss: 0.3365 - val_accuracy: 0.8908
Epoch 1/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.5362 - accuracy: 0.8
050 - val_loss: 0.4085 - val_accuracy: 0.8508
Epoch 2/10
1500/1500 [==============================] - 17s 12ms/step - loss: 0.3642 - accuracy: 0.8
657 - val_loss: 0.3545 - val_accuracy: 0.8711
Epoch 3/10
1500/1500 [==============================] - 17s 12ms/step - loss: 0.3176 - accuracy: 0.8
811 - val_loss: 0.3283 - val_accuracy: 0.8802
Epoch 4/10
1500/1500 [==============================] - 17s 12ms/step - loss: 0.2871 - accuracy: 0.8
919 - val_loss: 0.3067 - val_accuracy: 0.8864
Epoch 5/10
1500/1500 [==============================] - 18s 12ms/step - loss: 0.2605 - accuracy: 0.9
016 - val_loss: 0.3269 - val_accuracy: 0.8819
Epoch 6/10
1500/1500 [==============================] - 19s 12ms/step - loss: 0.2398 - accuracy: 0.9
112 - val_loss: 0.2934 - val_accuracy: 0.8915
Epoch 7/10
1500/1500 [==============================] - 19s 13ms/step - loss: 0.2202 - accuracy: 0.9
166 - val_loss: 0.3009 - val_accuracy: 0.8892
Epoch 8/10
1500/1500 [==============================] - 17s 12ms/step - loss: 0.2026 - accuracy: 0.9
226 - val_loss: 0.3100 - val_accuracy: 0.8918
Epoch 9/10
1500/1500 [==============================] - 17s 12ms/step - loss: 0.1835 - accuracy: 0.9
307 - val_loss: 0.3060 - val_accuracy: 0.8949
Epoch 10/10
1500/1500 [==============================] - 17s 12ms/step - loss: 0.1673 - accuracy: 0.9
362 - val_loss: 0.3360 - val_accuracy: 0.8928
Epoch 1/10
1500/1500 [==============================] - 22s 14ms/step - loss: 0.5073 - accuracy: 0.8
176 - val_loss: 0.3897 - val_accuracy: 0.8586
Epoch 2/10
1500/1500 [==============================] - 19s 13ms/step - loss: 0.3410 - accuracy: 0.8
736 - val_loss: 0.3269 - val_accuracy: 0.8790
Epoch 3/10
1500/1500 [==============================] - 19s 13ms/step - loss: 0.2942 - accuracy: 0.8
915 - val_loss: 0.3080 - val_accuracy: 0.8876
Epoch 4/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.2604 - accuracy: 0.9
022 - val_loss: 0.2975 - val_accuracy: 0.8939
Epoch 5/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.2311 - accuracy: 0.9
135 - val_loss: 0.2931 - val_accuracy: 0.8929
Epoch 6/10
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1500/1500 [==============================] - 21s 14ms/step - loss: 0.2072 - accuracy: 0.9
226 - val_loss: 0.2850 - val_accuracy: 0.8978
Epoch 7/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.1839 - accuracy: 0.9
315 - val_loss: 0.2923 - val_accuracy: 0.8997
Epoch 8/10
1500/1500 [==============================] - 19s 13ms/step - loss: 0.1623 - accuracy: 0.9
381 - val_loss: 0.3114 - val_accuracy: 0.8957
Epoch 9/10
1500/1500 [==============================] - 19s 13ms/step - loss: 0.1415 - accuracy: 0.9
467 - val_loss: 0.3239 - val_accuracy: 0.8943
Epoch 10/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.1236 - accuracy: 0.9
533 - val_loss: 0.3623 - val_accuracy: 0.8957
Epoch 1/10
1500/1500 [==============================] - 23s 15ms/step - loss: 0.5204 - accuracy: 0.8
117 - val_loss: 0.4087 - val_accuracy: 0.8489
Epoch 2/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.3479 - accuracy: 0.8
708 - val_loss: 0.3467 - val_accuracy: 0.8730
Epoch 3/10
1500/1500 [==============================] - 22s 14ms/step - loss: 0.2981 - accuracy: 0.8
880 - val_loss: 0.3137 - val_accuracy: 0.8846
Epoch 4/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.2634 - accuracy: 0.9
000 - val_loss: 0.3046 - val_accuracy: 0.8893
Epoch 5/10
1500/1500 [==============================] - 22s 14ms/step - loss: 0.2351 - accuracy: 0.9
107 - val_loss: 0.3090 - val_accuracy: 0.8881
Epoch 6/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.2094 - accuracy: 0.9
211 - val_loss: 0.3017 - val_accuracy: 0.8921
Epoch 7/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.1867 - accuracy: 0.9
299 - val_loss: 0.3142 - val_accuracy: 0.8919
Epoch 8/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.1662 - accuracy: 0.9
366 - val_loss: 0.3316 - val_accuracy: 0.8929
Epoch 9/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.1479 - accuracy: 0.9
444 - val_loss: 0.3404 - val_accuracy: 0.8930
Epoch 10/10
1500/1500 [==============================] - 23s 16ms/step - loss: 0.1295 - accuracy: 0.9
507 - val_loss: 0.3659 - val_accuracy: 0.8882
Epoch 1/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.4899 - accuracy: 0.8
227 - val_loss: 0.3753 - val_accuracy: 0.8620
Epoch 2/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.3295 - accuracy: 0.8
789 - val_loss: 0.3225 - val_accuracy: 0.8808
Epoch 3/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.2808 - accuracy: 0.8
949 - val_loss: 0.2980 - val_accuracy: 0.8929
Epoch 4/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.2430 - accuracy: 0.9
090 - val_loss: 0.3016 - val_accuracy: 0.8917
Epoch 5/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.2116 - accuracy: 0.9
209 - val_loss: 0.2884 - val_accuracy: 0.8947
Epoch 6/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.1803 - accuracy: 0.9
320 - val_loss: 0.2958 - val_accuracy: 0.8996
Epoch 7/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.1546 - accuracy: 0.9
416 - val_loss: 0.3031 - val_accuracy: 0.8997
Epoch 8/10
1500/1500 [==============================] - 28s 18ms/step - loss: 0.1322 - accuracy: 0.9
501 - val_loss: 0.3313 - val_accuracy: 0.8992
Epoch 9/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.1128 - accuracy: 0.9
574 - val_loss: 0.3427 - val_accuracy: 0.8992
Epoch 10/10
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1500/1500 [==============================] - 27s 18ms/step - loss: 0.0942 - accuracy: 0.9
647 - val_loss: 0.3631 - val_accuracy: 0.8965
Epoch 1/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.4915 - accuracy: 0.8
219 - val_loss: 0.3906 - val_accuracy: 0.8531
Epoch 2/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.3328 - accuracy: 0.8
772 - val_loss: 0.3340 - val_accuracy: 0.8781
Epoch 3/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2839 - accuracy: 0.8
929 - val_loss: 0.2988 - val_accuracy: 0.8929
Epoch 4/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2456 - accuracy: 0.9
078 - val_loss: 0.2879 - val_accuracy: 0.8952
Epoch 5/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2152 - accuracy: 0.9
194 - val_loss: 0.2980 - val_accuracy: 0.8889
Epoch 6/10
1500/1500 [==============================] - 31s 21ms/step - loss: 0.1869 - accuracy: 0.9
299 - val_loss: 0.2826 - val_accuracy: 0.8981
Epoch 7/10
1500/1500 [==============================] - 31s 21ms/step - loss: 0.1619 - accuracy: 0.9
387 - val_loss: 0.3025 - val_accuracy: 0.8977
Epoch 8/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.1412 - accuracy: 0.9
470 - val_loss: 0.3245 - val_accuracy: 0.8952
Epoch 9/10
1500/1500 [==============================] - 32s 22ms/step - loss: 0.1233 - accuracy: 0.9
536 - val_loss: 0.3383 - val_accuracy: 0.8999
Epoch 10/10
1500/1500 [==============================] - 34s 23ms/step - loss: 0.1060 - accuracy: 0.9
593 - val_loss: 0.3614 - val_accuracy: 0.8977
Epoch 1/10
1500/1500 [==============================] - 22s 14ms/step - loss: 0.4705 - accuracy: 0.8
320 - val_loss: 0.3589 - val_accuracy: 0.8701
Epoch 2/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.3119 - accuracy: 0.8
852 - val_loss: 0.3112 - val_accuracy: 0.8867
Epoch 3/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.2659 - accuracy: 0.9
020 - val_loss: 0.2741 - val_accuracy: 0.8992
Epoch 4/10
1500/1500 [==============================] - 23s 15ms/step - loss: 0.2338 - accuracy: 0.9
133 - val_loss: 0.2790 - val_accuracy: 0.8962
Epoch 5/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.2052 - accuracy: 0.9
241 - val_loss: 0.2777 - val_accuracy: 0.8972
Epoch 6/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.1823 - accuracy: 0.9
317 - val_loss: 0.2650 - val_accuracy: 0.9056
Epoch 7/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.1585 - accuracy: 0.9
405 - val_loss: 0.2694 - val_accuracy: 0.9070
Epoch 8/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.1388 - accuracy: 0.9
489 - val_loss: 0.2913 - val_accuracy: 0.9077
Epoch 9/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.1194 - accuracy: 0.9
556 - val_loss: 0.3080 - val_accuracy: 0.9044
Epoch 10/10
1500/1500 [==============================] - 23s 15ms/step - loss: 0.1033 - accuracy: 0.9
612 - val_loss: 0.3283 - val_accuracy: 0.9034
Epoch 1/10
1500/1500 [==============================] - 31s 20ms/step - loss: 0.4890 - accuracy: 0.8
222 - val_loss: 0.3627 - val_accuracy: 0.8650
Epoch 2/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.3182 - accuracy: 0.8
826 - val_loss: 0.3036 - val_accuracy: 0.8881
Epoch 3/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.2682 - accuracy: 0.8
993 - val_loss: 0.2808 - val_accuracy: 0.8972
Epoch 4/10
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1500/1500 [==============================] - 27s 18ms/step - loss: 0.2362 - accuracy: 0.9
119 - val_loss: 0.2780 - val_accuracy: 0.8967
Epoch 5/10
1500/1500 [==============================] - 29s 20ms/step - loss: 0.2078 - accuracy: 0.9
222 - val_loss: 0.2745 - val_accuracy: 0.9006
Epoch 6/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.1854 - accuracy: 0.9
309 - val_loss: 0.2723 - val_accuracy: 0.9046
Epoch 7/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.1650 - accuracy: 0.9
381 - val_loss: 0.2754 - val_accuracy: 0.9062
Epoch 8/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.1488 - accuracy: 0.9
441 - val_loss: 0.2819 - val_accuracy: 0.9064
Epoch 9/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.1285 - accuracy: 0.9
519 - val_loss: 0.3105 - val_accuracy: 0.8997
Epoch 10/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.1133 - accuracy: 0.9
577 - val_loss: 0.3183 - val_accuracy: 0.9030
Epoch 1/10
1500/1500 [==============================] - 31s 20ms/step - loss: 0.4508 - accuracy: 0.8
372 - val_loss: 0.3440 - val_accuracy: 0.8725
Epoch 2/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2977 - accuracy: 0.8
902 - val_loss: 0.2928 - val_accuracy: 0.8889
Epoch 3/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2480 - accuracy: 0.9
081 - val_loss: 0.2665 - val_accuracy: 0.9035
Epoch 4/10
1500/1500 [==============================] - 29s 20ms/step - loss: 0.2106 - accuracy: 0.9
214 - val_loss: 0.2683 - val_accuracy: 0.9030
Epoch 5/10
1500/1500 [==============================] - 29s 20ms/step - loss: 0.1777 - accuracy: 0.9
334 - val_loss: 0.2625 - val_accuracy: 0.9083
Epoch 6/10
1500/1500 [==============================] - 31s 20ms/step - loss: 0.1492 - accuracy: 0.9
427 - val_loss: 0.2661 - val_accuracy: 0.9104
Epoch 7/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.1225 - accuracy: 0.9
536 - val_loss: 0.2802 - val_accuracy: 0.9089
Epoch 8/10
1500/1500 [==============================] - 29s 20ms/step - loss: 0.1025 - accuracy: 0.9
619 - val_loss: 0.3213 - val_accuracy: 0.9078
Epoch 9/10
1500/1500 [==============================] - 29s 20ms/step - loss: 0.0822 - accuracy: 0.9
685 - val_loss: 0.3337 - val_accuracy: 0.9066
Epoch 10/10
1500/1500 [==============================] - 29s 20ms/step - loss: 0.0665 - accuracy: 0.9
750 - val_loss: 0.3671 - val_accuracy: 0.9068
Epoch 1/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.4624 - accuracy: 0.8
309 - val_loss: 0.3528 - val_accuracy: 0.8680
Epoch 2/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.3027 - accuracy: 0.8
885 - val_loss: 0.3046 - val_accuracy: 0.8864
Epoch 3/10
1500/1500 [==============================] - 47s 32ms/step - loss: 0.2530 - accuracy: 0.9
060 - val_loss: 0.2755 - val_accuracy: 0.8997
Epoch 4/10
1500/1500 [==============================] - 47s 32ms/step - loss: 0.2163 - accuracy: 0.9
208 - val_loss: 0.2789 - val_accuracy: 0.8971
Epoch 5/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.1829 - accuracy: 0.9
323 - val_loss: 0.2767 - val_accuracy: 0.9013
Epoch 6/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.1577 - accuracy: 0.9
406 - val_loss: 0.2771 - val_accuracy: 0.9070
Epoch 7/10
1500/1500 [==============================] - 47s 32ms/step - loss: 0.1333 - accuracy: 0.9
504 - val_loss: 0.2893 - val_accuracy: 0.9023
Epoch 8/10
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1500/1500 [==============================] - 47s 32ms/step - loss: 0.1120 - accuracy: 0.9
586 - val_loss: 0.3168 - val_accuracy: 0.9040
Epoch 9/10
1500/1500 [==============================] - 47s 32ms/step - loss: 0.0944 - accuracy: 0.9
653 - val_loss: 0.3432 - val_accuracy: 0.9052
Epoch 10/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.0794 - accuracy: 0.9
697 - val_loss: 0.3518 - val_accuracy: 0.9054
Epoch 1/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.4391 - accuracy: 0.8
423 - val_loss: 0.3393 - val_accuracy: 0.8755
Epoch 2/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.2888 - accuracy: 0.8
931 - val_loss: 0.2852 - val_accuracy: 0.8909
Epoch 3/10
1500/1500 [==============================] - 44s 29ms/step - loss: 0.2399 - accuracy: 0.9
111 - val_loss: 0.2649 - val_accuracy: 0.9012
Epoch 4/10
1500/1500 [==============================] - 44s 29ms/step - loss: 0.1989 - accuracy: 0.9
266 - val_loss: 0.2763 - val_accuracy: 0.9018
Epoch 5/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.1648 - accuracy: 0.9
378 - val_loss: 0.2743 - val_accuracy: 0.9048
Epoch 6/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.1351 - accuracy: 0.9
496 - val_loss: 0.2848 - val_accuracy: 0.9046
Epoch 7/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.1075 - accuracy: 0.9
602 - val_loss: 0.2926 - val_accuracy: 0.9091
Epoch 8/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.0869 - accuracy: 0.9
668 - val_loss: 0.3198 - val_accuracy: 0.9083
Epoch 9/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.0662 - accuracy: 0.9
758 - val_loss: 0.3805 - val_accuracy: 0.9068
Epoch 10/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.0544 - accuracy: 0.9
805 - val_loss: 0.3931 - val_accuracy: 0.9079
Epoch 1/10
1500/1500 [==============================] - 78s 51ms/step - loss: 0.4393 - accuracy: 0.8
402 - val_loss: 0.3341 - val_accuracy: 0.8733
Epoch 2/10
1500/1500 [==============================] - 77s 51ms/step - loss: 0.2864 - accuracy: 0.8
948 - val_loss: 0.2908 - val_accuracy: 0.8898
Epoch 3/10
1500/1500 [==============================] - 75s 50ms/step - loss: 0.2340 - accuracy: 0.9
129 - val_loss: 0.2643 - val_accuracy: 0.9004
Epoch 4/10
1500/1500 [==============================] - 80s 53ms/step - loss: 0.1949 - accuracy: 0.9
282 - val_loss: 0.2794 - val_accuracy: 0.9023
Epoch 5/10
1500/1500 [==============================] - 76s 50ms/step - loss: 0.1614 - accuracy: 0.9
398 - val_loss: 0.2628 - val_accuracy: 0.9049
Epoch 6/10
1500/1500 [==============================] - 75s 50ms/step - loss: 0.1320 - accuracy: 0.9
506 - val_loss: 0.2729 - val_accuracy: 0.9097
Epoch 7/10
1500/1500 [==============================] - 75s 50ms/step - loss: 0.1072 - accuracy: 0.9
605 - val_loss: 0.2784 - val_accuracy: 0.9127
Epoch 8/10
1500/1500 [==============================] - 75s 50ms/step - loss: 0.0873 - accuracy: 0.9
662 - val_loss: 0.3596 - val_accuracy: 0.9053
Epoch 9/10
1500/1500 [==============================] - 74s 50ms/step - loss: 0.0708 - accuracy: 0.9
735 - val_loss: 0.3750 - val_accuracy: 0.9066
Epoch 10/10
1500/1500 [==============================] - 75s 50ms/step - loss: 0.0604 - accuracy: 0.9
770 - val_loss: 0.4246 - val_accuracy: 0.9034
Epoch 1/10
1500/1500 [==============================] - 23s 14ms/step - loss: 0.5047 - accuracy: 0.8
169 - val_loss: 0.3884 - val_accuracy: 0.8583
Epoch 2/10
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1500/1500 [==============================] - 21s 14ms/step - loss: 0.3443 - accuracy: 0.8
725 - val_loss: 0.3432 - val_accuracy: 0.8744
Epoch 3/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.3017 - accuracy: 0.8
876 - val_loss: 0.3181 - val_accuracy: 0.8835
Epoch 4/10
1500/1500 [==============================] - 20s 13ms/step - loss: 0.2708 - accuracy: 0.8
979 - val_loss: 0.2957 - val_accuracy: 0.8901
Epoch 5/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.2430 - accuracy: 0.9
096 - val_loss: 0.2961 - val_accuracy: 0.8916
Epoch 6/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.2186 - accuracy: 0.9
181 - val_loss: 0.2936 - val_accuracy: 0.8928
Epoch 7/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.1978 - accuracy: 0.9
266 - val_loss: 0.2949 - val_accuracy: 0.8947
Epoch 8/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.1775 - accuracy: 0.9
325 - val_loss: 0.3044 - val_accuracy: 0.8956
Epoch 9/10
1500/1500 [==============================] - 21s 14ms/step - loss: 0.1608 - accuracy: 0.9
400 - val_loss: 0.3110 - val_accuracy: 0.8991
Epoch 10/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.1421 - accuracy: 0.9
467 - val_loss: 0.3314 - val_accuracy: 0.8935
Epoch 1/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.5348 - accuracy: 0.8
068 - val_loss: 0.4184 - val_accuracy: 0.8455
Epoch 2/10
1500/1500 [==============================] - 25s 17ms/step - loss: 0.3641 - accuracy: 0.8
650 - val_loss: 0.3543 - val_accuracy: 0.8704
Epoch 3/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.3133 - accuracy: 0.8
829 - val_loss: 0.3174 - val_accuracy: 0.8843
Epoch 4/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.2808 - accuracy: 0.8
936 - val_loss: 0.3000 - val_accuracy: 0.8894
Epoch 5/10
1500/1500 [==============================] - 25s 16ms/step - loss: 0.2550 - accuracy: 0.9
036 - val_loss: 0.3183 - val_accuracy: 0.8825
Epoch 6/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.2306 - accuracy: 0.9
143 - val_loss: 0.2855 - val_accuracy: 0.8953
Epoch 7/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.2114 - accuracy: 0.9
202 - val_loss: 0.3025 - val_accuracy: 0.8928
Epoch 8/10
1500/1500 [==============================] - 22s 15ms/step - loss: 0.1924 - accuracy: 0.9
270 - val_loss: 0.2987 - val_accuracy: 0.8974
Epoch 9/10
1500/1500 [==============================] - 25s 17ms/step - loss: 0.1738 - accuracy: 0.9
350 - val_loss: 0.2991 - val_accuracy: 0.8985
Epoch 10/10
1500/1500 [==============================] - 24s 16ms/step - loss: 0.1593 - accuracy: 0.9
403 - val_loss: 0.3143 - val_accuracy: 0.8947
Epoch 1/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.4858 - accuracy: 0.8
233 - val_loss: 0.4000 - val_accuracy: 0.8533
Epoch 2/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.3329 - accuracy: 0.8
775 - val_loss: 0.3264 - val_accuracy: 0.8787
Epoch 3/10
1500/1500 [==============================] - 25s 17ms/step - loss: 0.2864 - accuracy: 0.8
928 - val_loss: 0.3009 - val_accuracy: 0.8896
Epoch 4/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.2523 - accuracy: 0.9
045 - val_loss: 0.3041 - val_accuracy: 0.8876
Epoch 5/10
1500/1500 [==============================] - 26s 18ms/step - loss: 0.2223 - accuracy: 0.9
163 - val_loss: 0.2906 - val_accuracy: 0.8943
Epoch 6/10
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1500/1500 [==============================] - 25s 17ms/step - loss: 0.1965 - accuracy: 0.9
257 - val_loss: 0.2889 - val_accuracy: 0.8971
Epoch 7/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.1718 - accuracy: 0.9
356 - val_loss: 0.2903 - val_accuracy: 0.8984
Epoch 8/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.1487 - accuracy: 0.9
435 - val_loss: 0.3136 - val_accuracy: 0.8967
Epoch 9/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.1303 - accuracy: 0.9
506 - val_loss: 0.3340 - val_accuracy: 0.8984
Epoch 10/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.1123 - accuracy: 0.9
573 - val_loss: 0.3547 - val_accuracy: 0.8956
Epoch 1/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.5154 - accuracy: 0.8
132 - val_loss: 0.3901 - val_accuracy: 0.8567
Epoch 2/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.3450 - accuracy: 0.8
736 - val_loss: 0.3450 - val_accuracy: 0.8723
Epoch 3/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2975 - accuracy: 0.8
873 - val_loss: 0.3123 - val_accuracy: 0.8848
Epoch 4/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2608 - accuracy: 0.9
020 - val_loss: 0.3043 - val_accuracy: 0.8915
Epoch 5/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2320 - accuracy: 0.9
132 - val_loss: 0.3003 - val_accuracy: 0.8928
Epoch 6/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2071 - accuracy: 0.9
217 - val_loss: 0.2853 - val_accuracy: 0.8981
Epoch 7/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.1832 - accuracy: 0.9
310 - val_loss: 0.2929 - val_accuracy: 0.9013
Epoch 8/10
1500/1500 [==============================] - 32s 22ms/step - loss: 0.1633 - accuracy: 0.9
376 - val_loss: 0.3067 - val_accuracy: 0.8983
Epoch 9/10
1500/1500 [==============================] - 32s 22ms/step - loss: 0.1457 - accuracy: 0.9
452 - val_loss: 0.3245 - val_accuracy: 0.8950
Epoch 10/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.1297 - accuracy: 0.9
504 - val_loss: 0.3683 - val_accuracy: 0.8902
Epoch 1/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.4776 - accuracy: 0.8
272 - val_loss: 0.3698 - val_accuracy: 0.8624
Epoch 2/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.3233 - accuracy: 0.8
794 - val_loss: 0.3171 - val_accuracy: 0.8798
Epoch 3/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.2740 - accuracy: 0.8
965 - val_loss: 0.2928 - val_accuracy: 0.8935
Epoch 4/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.2382 - accuracy: 0.9
088 - val_loss: 0.2920 - val_accuracy: 0.8963
Epoch 5/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.2058 - accuracy: 0.9
221 - val_loss: 0.2890 - val_accuracy: 0.8962
Epoch 6/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.1770 - accuracy: 0.9
327 - val_loss: 0.2916 - val_accuracy: 0.8992
Epoch 7/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.1514 - accuracy: 0.9
425 - val_loss: 0.2991 - val_accuracy: 0.8994
Epoch 8/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.1301 - accuracy: 0.9
510 - val_loss: 0.3251 - val_accuracy: 0.9010
Epoch 9/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.1099 - accuracy: 0.9
589 - val_loss: 0.3350 - val_accuracy: 0.9028
Epoch 10/10
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1500/1500 [==============================] - 37s 25ms/step - loss: 0.0930 - accuracy: 0.9
644 - val_loss: 0.3912 - val_accuracy: 0.8969
Epoch 1/10
1500/1500 [==============================] - 63s 41ms/step - loss: 0.4924 - accuracy: 0.8
208 - val_loss: 0.3828 - val_accuracy: 0.8598
Epoch 2/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.3313 - accuracy: 0.8
771 - val_loss: 0.3356 - val_accuracy: 0.8783
Epoch 3/10
1500/1500 [==============================] - 64s 43ms/step - loss: 0.2836 - accuracy: 0.8
928 - val_loss: 0.3063 - val_accuracy: 0.8868
Epoch 4/10
1500/1500 [==============================] - 61s 41ms/step - loss: 0.2464 - accuracy: 0.9
073 - val_loss: 0.3055 - val_accuracy: 0.8909
Epoch 5/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.2147 - accuracy: 0.9
189 - val_loss: 0.2943 - val_accuracy: 0.8963
Epoch 6/10
1500/1500 [==============================] - 61s 41ms/step - loss: 0.1848 - accuracy: 0.9
306 - val_loss: 0.2958 - val_accuracy: 0.8952
Epoch 7/10
1500/1500 [==============================] - 61s 41ms/step - loss: 0.1626 - accuracy: 0.9
376 - val_loss: 0.2907 - val_accuracy: 0.8980
Epoch 8/10
1500/1500 [==============================] - 60s 40ms/step - loss: 0.1408 - accuracy: 0.9
458 - val_loss: 0.3167 - val_accuracy: 0.8985
Epoch 9/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.1235 - accuracy: 0.9
533 - val_loss: 0.3500 - val_accuracy: 0.8948
Epoch 10/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.1094 - accuracy: 0.9
581 - val_loss: 0.3685 - val_accuracy: 0.8924
Epoch 1/10
1500/1500 [==============================] - 38s 24ms/step - loss: 0.4683 - accuracy: 0.8
327 - val_loss: 0.3582 - val_accuracy: 0.8637
Epoch 2/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.3109 - accuracy: 0.8
859 - val_loss: 0.3054 - val_accuracy: 0.8861
Epoch 3/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2649 - accuracy: 0.9
011 - val_loss: 0.2790 - val_accuracy: 0.8964
Epoch 4/10
1500/1500 [==============================] - 34s 22ms/step - loss: 0.2318 - accuracy: 0.9
133 - val_loss: 0.2759 - val_accuracy: 0.8988
Epoch 5/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2019 - accuracy: 0.9
242 - val_loss: 0.2661 - val_accuracy: 0.9021
Epoch 6/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.1783 - accuracy: 0.9
338 - val_loss: 0.2679 - val_accuracy: 0.9032
Epoch 7/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.1552 - accuracy: 0.9
417 - val_loss: 0.2761 - val_accuracy: 0.9055
Epoch 8/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.1355 - accuracy: 0.9
501 - val_loss: 0.3005 - val_accuracy: 0.9047
Epoch 9/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.1173 - accuracy: 0.9
554 - val_loss: 0.3221 - val_accuracy: 0.9022
Epoch 10/10
1500/1500 [==============================] - 34s 22ms/step - loss: 0.1012 - accuracy: 0.9
617 - val_loss: 0.3365 - val_accuracy: 0.9013
Epoch 1/10
1500/1500 [==============================] - 59s 38ms/step - loss: 0.4695 - accuracy: 0.8
297 - val_loss: 0.3605 - val_accuracy: 0.8633
Epoch 2/10
1500/1500 [==============================] - 54s 36ms/step - loss: 0.3079 - accuracy: 0.8
863 - val_loss: 0.2951 - val_accuracy: 0.8894
Epoch 3/10
1500/1500 [==============================] - 56s 37ms/step - loss: 0.2620 - accuracy: 0.9
025 - val_loss: 0.2892 - val_accuracy: 0.8927
Epoch 4/10
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1500/1500 [==============================] - 54s 36ms/step - loss: 0.2287 - accuracy: 0.9
147 - val_loss: 0.2819 - val_accuracy: 0.8990
Epoch 5/10
1500/1500 [==============================] - 58s 39ms/step - loss: 0.2001 - accuracy: 0.9
251 - val_loss: 0.2605 - val_accuracy: 0.9047
Epoch 6/10
1500/1500 [==============================] - 56s 37ms/step - loss: 0.1765 - accuracy: 0.9
334 - val_loss: 0.2747 - val_accuracy: 0.9013
Epoch 7/10
1500/1500 [==============================] - 55s 37ms/step - loss: 0.1550 - accuracy: 0.9
425 - val_loss: 0.2856 - val_accuracy: 0.9028
Epoch 8/10
1500/1500 [==============================] - 56s 37ms/step - loss: 0.1360 - accuracy: 0.9
492 - val_loss: 0.2909 - val_accuracy: 0.9036
Epoch 9/10
1500/1500 [==============================] - 55s 37ms/step - loss: 0.1160 - accuracy: 0.9
556 - val_loss: 0.3119 - val_accuracy: 0.9024
Epoch 10/10
1500/1500 [==============================] - 58s 39ms/step - loss: 0.1017 - accuracy: 0.9
616 - val_loss: 0.3295 - val_accuracy: 0.8996
Epoch 1/10
1500/1500 [==============================] - 53s 35ms/step - loss: 0.4428 - accuracy: 0.8
400 - val_loss: 0.3383 - val_accuracy: 0.8752
Epoch 2/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2924 - accuracy: 0.8
924 - val_loss: 0.3029 - val_accuracy: 0.8855
Epoch 3/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2442 - accuracy: 0.9
090 - val_loss: 0.2656 - val_accuracy: 0.9013
Epoch 4/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2082 - accuracy: 0.9
226 - val_loss: 0.2663 - val_accuracy: 0.9037
Epoch 5/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.1763 - accuracy: 0.9
338 - val_loss: 0.2660 - val_accuracy: 0.9096
Epoch 6/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.1476 - accuracy: 0.9
443 - val_loss: 0.2694 - val_accuracy: 0.9081
Epoch 7/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.1214 - accuracy: 0.9
549 - val_loss: 0.2877 - val_accuracy: 0.9086
Epoch 8/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.0972 - accuracy: 0.9
632 - val_loss: 0.3232 - val_accuracy: 0.9046
Epoch 9/10
1500/1500 [==============================] - 49s 33ms/step - loss: 0.0798 - accuracy: 0.9
710 - val_loss: 0.3603 - val_accuracy: 0.9057
Epoch 10/10
1500/1500 [==============================] - 49s 33ms/step - loss: 0.0645 - accuracy: 0.9
763 - val_loss: 0.3852 - val_accuracy: 0.9078
Epoch 1/10
1500/1500 [==============================] - 82s 54ms/step - loss: 0.4512 - accuracy: 0.8
356 - val_loss: 0.3547 - val_accuracy: 0.8677
Epoch 2/10
1500/1500 [==============================] - 83s 55ms/step - loss: 0.2925 - accuracy: 0.8
912 - val_loss: 0.2903 - val_accuracy: 0.8921
Epoch 3/10
1500/1500 [==============================] - 82s 55ms/step - loss: 0.2443 - accuracy: 0.9
079 - val_loss: 0.2712 - val_accuracy: 0.8997
Epoch 4/10
1500/1500 [==============================] - 83s 56ms/step - loss: 0.2075 - accuracy: 0.9
228 - val_loss: 0.2687 - val_accuracy: 0.9028
Epoch 5/10
1500/1500 [==============================] - 83s 55ms/step - loss: 0.1771 - accuracy: 0.9
340 - val_loss: 0.2705 - val_accuracy: 0.9075
Epoch 6/10
1500/1500 [==============================] - 83s 55ms/step - loss: 0.1510 - accuracy: 0.9
436 - val_loss: 0.2705 - val_accuracy: 0.9077
Epoch 7/10
1500/1500 [==============================] - 82s 55ms/step - loss: 0.1267 - accuracy: 0.9
523 - val_loss: 0.2848 - val_accuracy: 0.9093
Epoch 8/10
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1500/1500 [==============================] - 83s 55ms/step - loss: 0.1076 - accuracy: 0.9
599 - val_loss: 0.3103 - val_accuracy: 0.9065
Epoch 9/10
1500/1500 [==============================] - 82s 54ms/step - loss: 0.0900 - accuracy: 0.9
659 - val_loss: 0.3395 - val_accuracy: 0.9044
Epoch 10/10
1500/1500 [==============================] - 82s 55ms/step - loss: 0.0792 - accuracy: 0.9
698 - val_loss: 0.3456 - val_accuracy: 0.9055
Epoch 1/10
1500/1500 [==============================] - 88s 58ms/step - loss: 0.4322 - accuracy: 0.8
441 - val_loss: 0.3365 - val_accuracy: 0.8753
Epoch 2/10
1500/1500 [==============================] - 82s 55ms/step - loss: 0.2824 - accuracy: 0.8
950 - val_loss: 0.2867 - val_accuracy: 0.8923
Epoch 3/10
1500/1500 [==============================] - 82s 55ms/step - loss: 0.2306 - accuracy: 0.9
129 - val_loss: 0.2576 - val_accuracy: 0.9047
Epoch 4/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.1887 - accuracy: 0.9
295 - val_loss: 0.2596 - val_accuracy: 0.9056
Epoch 5/10
1500/1500 [==============================] - 88s 58ms/step - loss: 0.1548 - accuracy: 0.9
413 - val_loss: 0.2673 - val_accuracy: 0.9093
Epoch 6/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.1254 - accuracy: 0.9
516 - val_loss: 0.2803 - val_accuracy: 0.9078
Epoch 7/10
1500/1500 [==============================] - 82s 55ms/step - loss: 0.0996 - accuracy: 0.9
623 - val_loss: 0.2867 - val_accuracy: 0.9108
Epoch 8/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.0799 - accuracy: 0.9
704 - val_loss: 0.3407 - val_accuracy: 0.9078
Epoch 9/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.0624 - accuracy: 0.9
770 - val_loss: 0.3856 - val_accuracy: 0.9050
Epoch 10/10
1500/1500 [==============================] - 82s 55ms/step - loss: 0.0537 - accuracy: 0.9
793 - val_loss: 0.3783 - val_accuracy: 0.9106
Epoch 1/10
1500/1500 [==============================] - 135s 89ms/step - loss: 0.4333 - accuracy: 0.
8423 - val_loss: 0.3401 - val_accuracy: 0.8728
Epoch 2/10
1500/1500 [==============================] - 137s 91ms/step - loss: 0.2827 - accuracy: 0.
8960 - val_loss: 0.2978 - val_accuracy: 0.8880
Epoch 3/10
1500/1500 [==============================] - 132s 88ms/step - loss: 0.2315 - accuracy: 0.
9148 - val_loss: 0.2648 - val_accuracy: 0.9032
Epoch 4/10
1500/1500 [==============================] - 137s 92ms/step - loss: 0.1918 - accuracy: 0.
9291 - val_loss: 0.2644 - val_accuracy: 0.9040
Epoch 5/10
1500/1500 [==============================] - 134s 89ms/step - loss: 0.1558 - accuracy: 0.
9413 - val_loss: 0.2820 - val_accuracy: 0.9026
Epoch 6/10
1500/1500 [==============================] - 137s 91ms/step - loss: 0.1275 - accuracy: 0.
9519 - val_loss: 0.2804 - val_accuracy: 0.9077
Epoch 7/10
1500/1500 [==============================] - 137s 91ms/step - loss: 0.1043 - accuracy: 0.
9609 - val_loss: 0.2957 - val_accuracy: 0.9089
Epoch 8/10
1500/1500 [==============================] - 137s 91ms/step - loss: 0.0857 - accuracy: 0.
9672 - val_loss: 0.3351 - val_accuracy: 0.9047
Epoch 9/10
1500/1500 [==============================] - 134s 89ms/step - loss: 0.0704 - accuracy: 0.
9745 - val_loss: 0.3833 - val_accuracy: 0.9058
Epoch 10/10
1500/1500 [==============================] - 137s 91ms/step - loss: 0.0606 - accuracy: 0.
9775 - val_loss: 0.3723 - val_accuracy: 0.9070
Epoch 1/10
1500/1500 [==============================] - 34s 22ms/step - loss: 0.5082 - accuracy: 0.8
160 - val_loss: 0.3937 - val_accuracy: 0.8537
Epoch 2/10
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1500/1500 [==============================] - 30s 20ms/step - loss: 0.3426 - accuracy: 0.8
729 - val_loss: 0.3347 - val_accuracy: 0.8742
Epoch 3/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2966 - accuracy: 0.8
880 - val_loss: 0.3087 - val_accuracy: 0.8873
Epoch 4/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2636 - accuracy: 0.9
000 - val_loss: 0.3049 - val_accuracy: 0.8894
Epoch 5/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2370 - accuracy: 0.9
106 - val_loss: 0.3007 - val_accuracy: 0.8928
Epoch 6/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2130 - accuracy: 0.9
192 - val_loss: 0.2861 - val_accuracy: 0.8955
Epoch 7/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.1901 - accuracy: 0.9
294 - val_loss: 0.2870 - val_accuracy: 0.8979
Epoch 8/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.1706 - accuracy: 0.9
359 - val_loss: 0.3161 - val_accuracy: 0.8983
Epoch 9/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.1517 - accuracy: 0.9
433 - val_loss: 0.3285 - val_accuracy: 0.8982
Epoch 10/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.1335 - accuracy: 0.9
499 - val_loss: 0.3290 - val_accuracy: 0.8955
Epoch 1/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.5085 - accuracy: 0.8
142 - val_loss: 0.3963 - val_accuracy: 0.8550
Epoch 2/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.3515 - accuracy: 0.8
689 - val_loss: 0.3562 - val_accuracy: 0.8685
Epoch 3/10
1500/1500 [==============================] - 49s 32ms/step - loss: 0.3057 - accuracy: 0.8
859 - val_loss: 0.3180 - val_accuracy: 0.8848
Epoch 4/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2756 - accuracy: 0.8
953 - val_loss: 0.3033 - val_accuracy: 0.8898
Epoch 5/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2473 - accuracy: 0.9
064 - val_loss: 0.3098 - val_accuracy: 0.8899
Epoch 6/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2271 - accuracy: 0.9
139 - val_loss: 0.3015 - val_accuracy: 0.8910
Epoch 7/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2072 - accuracy: 0.9
213 - val_loss: 0.2880 - val_accuracy: 0.8977
Epoch 8/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.1888 - accuracy: 0.9
266 - val_loss: 0.3215 - val_accuracy: 0.8906
Epoch 9/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.1728 - accuracy: 0.9
350 - val_loss: 0.3004 - val_accuracy: 0.8966
Epoch 10/10
1500/1500 [==============================] - 49s 33ms/step - loss: 0.1547 - accuracy: 0.9
411 - val_loss: 0.3280 - val_accuracy: 0.8925
Epoch 1/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.4806 - accuracy: 0.8
245 - val_loss: 0.3716 - val_accuracy: 0.8633
Epoch 2/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.3279 - accuracy: 0.8
768 - val_loss: 0.3334 - val_accuracy: 0.8757
Epoch 3/10
1500/1500 [==============================] - 40s 26ms/step - loss: 0.2815 - accuracy: 0.8
943 - val_loss: 0.3017 - val_accuracy: 0.8889
Epoch 4/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.2458 - accuracy: 0.9
067 - val_loss: 0.2883 - val_accuracy: 0.8963
Epoch 5/10
1500/1500 [==============================] - 41s 28ms/step - loss: 0.2176 - accuracy: 0.9
174 - val_loss: 0.2932 - val_accuracy: 0.8954
Epoch 6/10
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1500/1500 [==============================] - 38s 25ms/step - loss: 0.1892 - accuracy: 0.9
291 - val_loss: 0.2843 - val_accuracy: 0.8976
Epoch 7/10
1500/1500 [==============================] - 42s 28ms/step - loss: 0.1660 - accuracy: 0.9
374 - val_loss: 0.2870 - val_accuracy: 0.9022
Epoch 8/10
1500/1500 [==============================] - 38s 26ms/step - loss: 0.1456 - accuracy: 0.9
433 - val_loss: 0.3111 - val_accuracy: 0.9004
Epoch 9/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.1260 - accuracy: 0.9
530 - val_loss: 0.3305 - val_accuracy: 0.8972
Epoch 10/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.1096 - accuracy: 0.9
590 - val_loss: 0.3534 - val_accuracy: 0.8973
Epoch 1/10
1500/1500 [==============================] - 71s 47ms/step - loss: 0.4991 - accuracy: 0.8
183 - val_loss: 0.3754 - val_accuracy: 0.8647
Epoch 2/10
1500/1500 [==============================] - 66s 44ms/step - loss: 0.3354 - accuracy: 0.8
759 - val_loss: 0.3439 - val_accuracy: 0.8757
Epoch 3/10
1500/1500 [==============================] - 67s 44ms/step - loss: 0.2881 - accuracy: 0.8
918 - val_loss: 0.3051 - val_accuracy: 0.8882
Epoch 4/10
1500/1500 [==============================] - 67s 44ms/step - loss: 0.2521 - accuracy: 0.9
054 - val_loss: 0.2995 - val_accuracy: 0.8923
Epoch 5/10
1500/1500 [==============================] - 69s 46ms/step - loss: 0.2205 - accuracy: 0.9
161 - val_loss: 0.3048 - val_accuracy: 0.8926
Epoch 6/10
1500/1500 [==============================] - 69s 46ms/step - loss: 0.1969 - accuracy: 0.9
264 - val_loss: 0.2835 - val_accuracy: 0.8987
Epoch 7/10
1500/1500 [==============================] - 67s 44ms/step - loss: 0.1744 - accuracy: 0.9
337 - val_loss: 0.2957 - val_accuracy: 0.8993
Epoch 8/10
1500/1500 [==============================] - 67s 45ms/step - loss: 0.1539 - accuracy: 0.9
417 - val_loss: 0.2991 - val_accuracy: 0.8997
Epoch 9/10
1500/1500 [==============================] - 69s 46ms/step - loss: 0.1372 - accuracy: 0.9
470 - val_loss: 0.3091 - val_accuracy: 0.8975
Epoch 10/10
1500/1500 [==============================] - 67s 45ms/step - loss: 0.1205 - accuracy: 0.9
539 - val_loss: 0.3497 - val_accuracy: 0.8974
Epoch 1/10
1500/1500 [==============================] - 70s 46ms/step - loss: 0.4664 - accuracy: 0.8
304 - val_loss: 0.3806 - val_accuracy: 0.8606
Epoch 2/10
1500/1500 [==============================] - 68s 46ms/step - loss: 0.3202 - accuracy: 0.8
792 - val_loss: 0.3148 - val_accuracy: 0.8826
Epoch 3/10
1500/1500 [==============================] - 67s 45ms/step - loss: 0.2717 - accuracy: 0.8
986 - val_loss: 0.3011 - val_accuracy: 0.8923
Epoch 4/10
1500/1500 [==============================] - 67s 45ms/step - loss: 0.2329 - accuracy: 0.9
115 - val_loss: 0.2807 - val_accuracy: 0.8958
Epoch 5/10
1500/1500 [==============================] - 69s 46ms/step - loss: 0.1996 - accuracy: 0.9
236 - val_loss: 0.2891 - val_accuracy: 0.9000
Epoch 6/10
1500/1500 [==============================] - 68s 45ms/step - loss: 0.1684 - accuracy: 0.9
351 - val_loss: 0.2933 - val_accuracy: 0.8956
Epoch 7/10
1500/1500 [==============================] - 67s 44ms/step - loss: 0.1416 - accuracy: 0.9
456 - val_loss: 0.3008 - val_accuracy: 0.8978
Epoch 8/10
1500/1500 [==============================] - 67s 45ms/step - loss: 0.1195 - accuracy: 0.9
542 - val_loss: 0.3400 - val_accuracy: 0.9022
Epoch 9/10
1500/1500 [==============================] - 67s 45ms/step - loss: 0.1008 - accuracy: 0.9
621 - val_loss: 0.3649 - val_accuracy: 0.9017
Epoch 10/10
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1500/1500 [==============================] - 69s 46ms/step - loss: 0.0848 - accuracy: 0.9
681 - val_loss: 0.3826 - val_accuracy: 0.8947
Epoch 1/10
1500/1500 [==============================] - 114s 76ms/step - loss: 0.4835 - accuracy: 0.
8231 - val_loss: 0.3693 - val_accuracy: 0.8631
Epoch 2/10
1500/1500 [==============================] - 110s 73ms/step - loss: 0.3246 - accuracy: 0.
8786 - val_loss: 0.3297 - val_accuracy: 0.8788
Epoch 3/10
1500/1500 [==============================] - 109s 73ms/step - loss: 0.2756 - accuracy: 0.
8962 - val_loss: 0.3045 - val_accuracy: 0.8900
Epoch 4/10
1500/1500 [==============================] - 109s 73ms/step - loss: 0.2388 - accuracy: 0.
9100 - val_loss: 0.2971 - val_accuracy: 0.8923
Epoch 5/10
1500/1500 [==============================] - 110s 73ms/step - loss: 0.2075 - accuracy: 0.
9220 - val_loss: 0.2992 - val_accuracy: 0.8904
Epoch 6/10
1500/1500 [==============================] - 110s 73ms/step - loss: 0.1797 - accuracy: 0.
9330 - val_loss: 0.2921 - val_accuracy: 0.8931
Epoch 7/10
1500/1500 [==============================] - 114s 76ms/step - loss: 0.1555 - accuracy: 0.
9410 - val_loss: 0.2944 - val_accuracy: 0.9023
Epoch 8/10
1500/1500 [==============================] - 109s 73ms/step - loss: 0.1360 - accuracy: 0.
9473 - val_loss: 0.3372 - val_accuracy: 0.8985
Epoch 9/10
1500/1500 [==============================] - 114s 76ms/step - loss: 0.1174 - accuracy: 0.
9552 - val_loss: 0.3452 - val_accuracy: 0.8997
Epoch 10/10
1500/1500 [==============================] - 109s 73ms/step - loss: 0.1006 - accuracy: 0.
9604 - val_loss: 0.3644 - val_accuracy: 0.8953
```
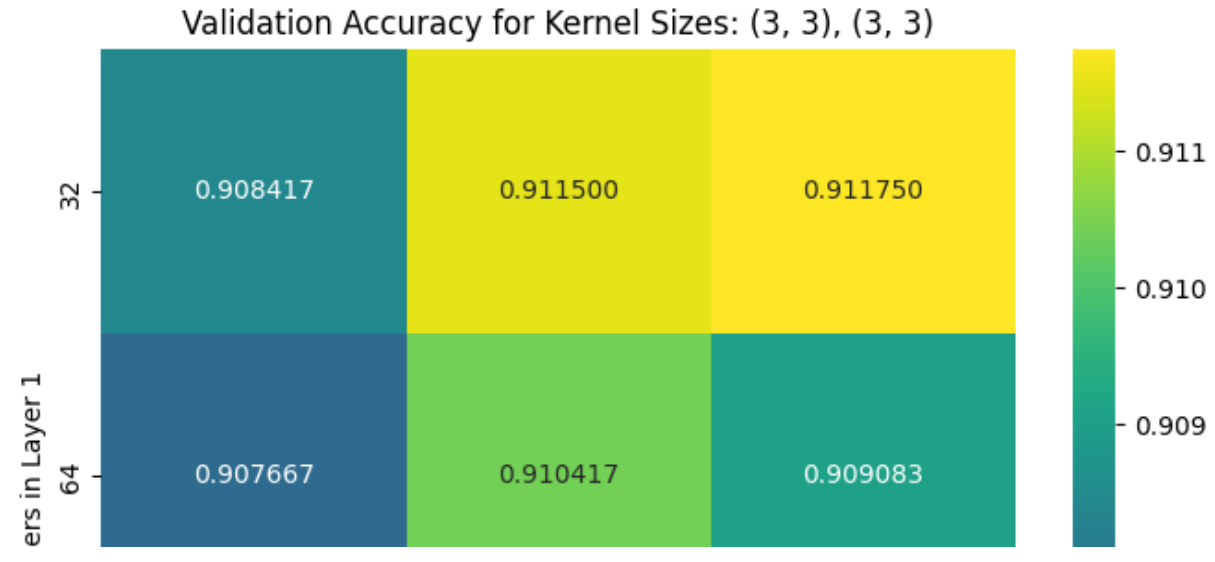
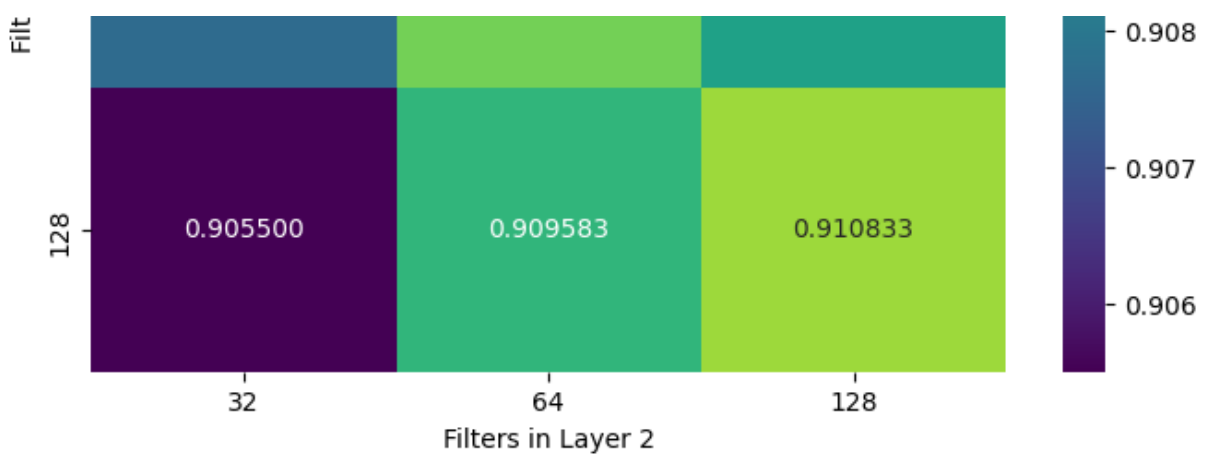
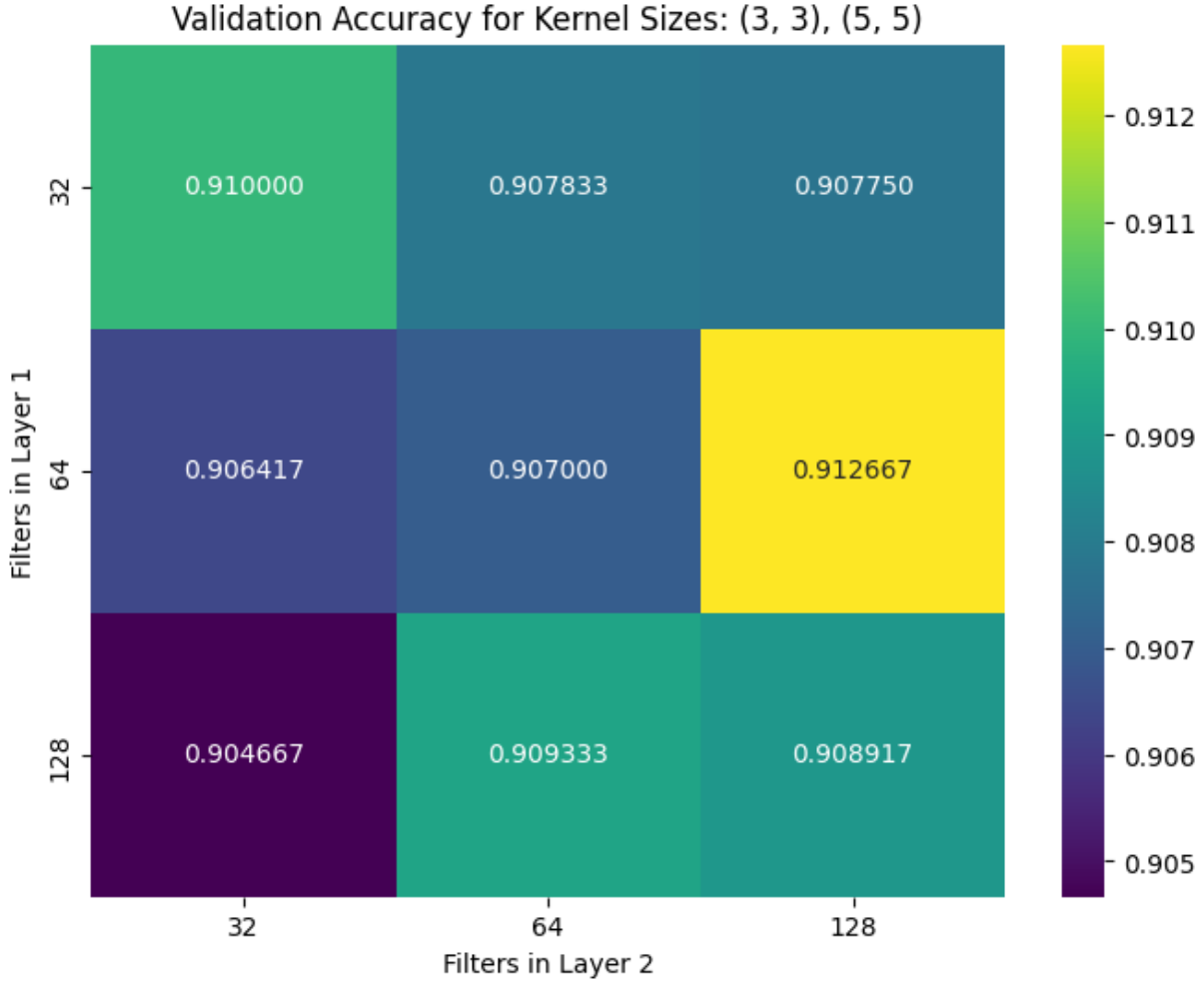
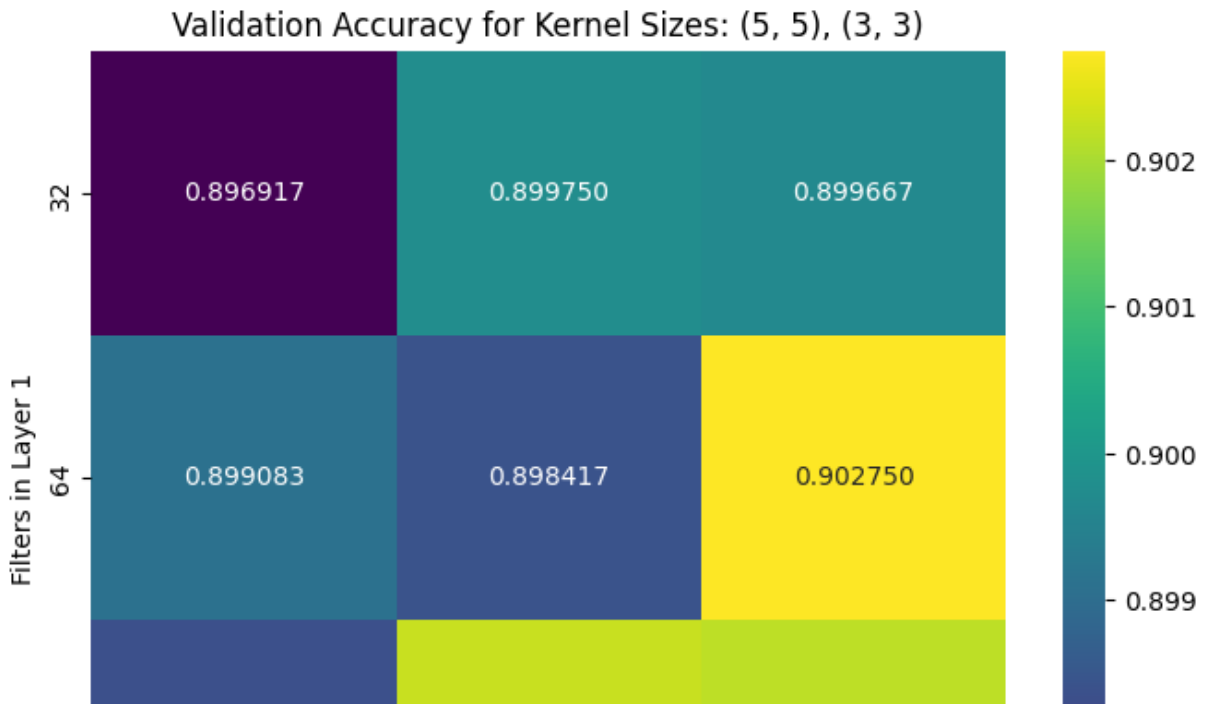

In [ ]:

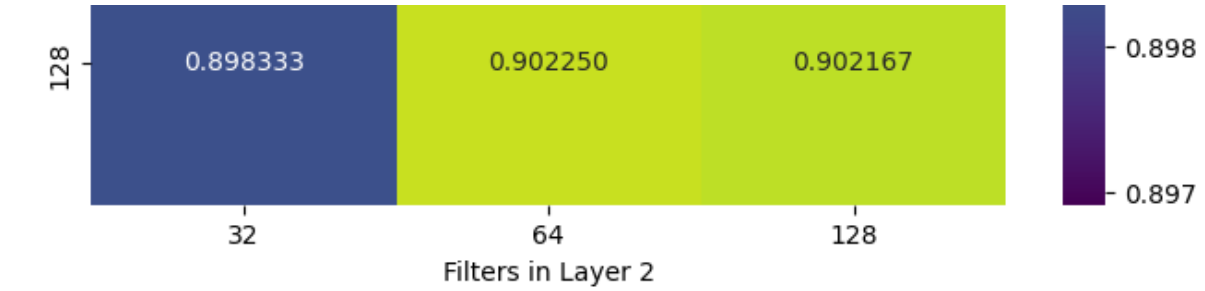
```
# Create a heatmap for each combination of kernel sizes
for kernel_size1 in kernel_sizes:
    for kernel_size2 in kernel_sizes:
        heatmap_data = np.zeros((len(filter_sizes), len(filter_sizes)))
        for filters1, k_size1, filters2, k_size2, accuracy in cnn_results:
            if k_size1 == kernel_size1 and k_size2 == kernel_size2:
                i = filter_sizes.index(filters1)
                j = filter_sizes.index(filters2)
                heatmap_data[i, j] = accuracy

        plt.figure(figsize=(8, 6))
        sns.heatmap(heatmap_data, annot=True, fmt=".6f", xticklabels=filter_sizes, ytick
labels=filter_sizes, cmap="viridis")
        plt.title(f"Validation Accuracy for Kernel Sizes: {kernel_size1}, {kernel_size2}
")
        plt.xlabel("Filters in Layer 2")
        plt.ylabel("Filters in Layer 1")
        plt.show()
```

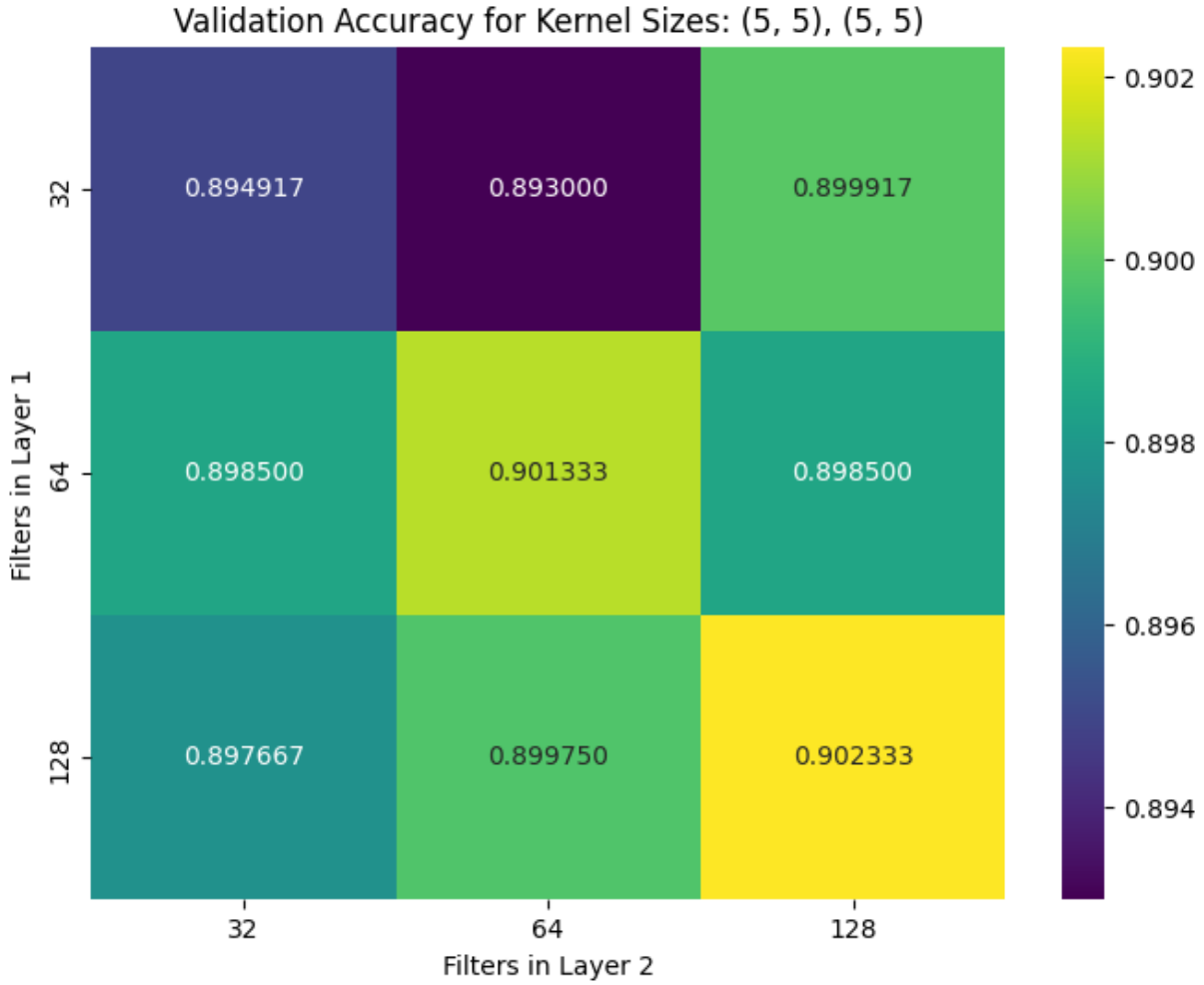



Filt
128
0.905500
0.909583
0.910833
32
64
128
Filters in Layer 2
0.908
0.907
0.906


Validation Accuracy for Kernel Sizes: (3, 3), (5, 5)
Filters in Layer 1
32
64
128
0.910000
0.907833
0.907750
0.906417
0.907000
0.912667
0.904667
0.909333
0.908917
32
64
128
Filters in Layer 2
0.912
0.911
0.910
0.909
0.908
0.907
0.906
0.905


Validation Accuracy for Kernel Sizes: (5, 5), (3, 3)
Filters in Layer 1
32
64
0.896917
0.899750
0.899667
0.899083
0.898417
0.902750
0.902
0.901
0.900
0.899





Additional Max Pooling Implementation

In [ ]:

```
def build_cnn_maxpool_model(filters1, kernel_size1, filters2, kernel_size2, pool_size):
    model = Sequential([
        Conv2D(filters1, kernel_size1, activation='relu', input_shape=(28, 28, 1)),
        MaxPooling2D(pool_size, pool_size),
        Conv2D(filters2, kernel_size2, activation='relu'),
        MaxPooling2D(pool_size, pool_size),
        Flatten(),
        Dense(128, activation='relu'),
        Dense(10, activation='softmax')
    ])
    return model
```

In [ ]:

```
# Initialize an empty list to store the results
maxpool_results = []

# Define ranges for hyperparameters
kernel_sizes = [(3, 3), (5, 5)]
filter_sizes = [32, 64]
pool_sizes = [2, 3]
```

```
best_maxpool_model = None
best_maxpool_accuracy = 0

# Grid search
for filters1 in filter_sizes:
    for kernel_size1 in kernel_sizes:
        for filters2 in filter_sizes:
            for kernel_size2 in kernel_sizes:
                for pool_size in pool_sizes:
                    maxpool_model = build_cnn_maxpool_model(filters1, kernel_size1, filt
ers2, kernel_size2, pool_size)
                    maxpool_history = compile_and_train(maxpool_model, x_train, y_train,
x_val, y_val)
                    maxpool_results.append((filters1, kernel_size1, filters2, kernel_siz
e2, pool_size, max(maxpool_history.history['val_accuracy'])))
                    if max(maxpool_history.history['val_accuracy']) > best_maxpool_accur
acy:
                        best_maxpool_accuracy = max(maxpool_history.history['val_accurac
y'])
                        best_maxpool_model = maxpool_model
```

```
Epoch 1/10
1500/1500 [==============================] - 40s 26ms/step - loss: 0.4942 - accuracy: 0.8
210 - val_loss: 0.3743 - val_accuracy: 0.8615
Epoch 2/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.3268 - accuracy: 0.8
799 - val_loss: 0.3176 - val_accuracy: 0.8825
Epoch 3/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.2849 - accuracy: 0.8
952 - val_loss: 0.2774 - val_accuracy: 0.8984
Epoch 4/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.2552 - accuracy: 0.9
059 - val_loss: 0.2715 - val_accuracy: 0.8997
Epoch 5/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.2303 - accuracy: 0.9
145 - val_loss: 0.2761 - val_accuracy: 0.8979
Epoch 6/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.2095 - accuracy: 0.9
218 - val_loss: 0.2644 - val_accuracy: 0.9064
Epoch 7/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.1942 - accuracy: 0.9
276 - val_loss: 0.2449 - val_accuracy: 0.9109
Epoch 8/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.1757 - accuracy: 0.9
340 - val_loss: 0.2652 - val_accuracy: 0.9089
Epoch 9/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.1607 - accuracy: 0.9
401 - val_loss: 0.2529 - val_accuracy: 0.9100
Epoch 10/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.1479 - accuracy: 0.9
441 - val_loss: 0.2549 - val_accuracy: 0.9120
Epoch 1/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.5862 - accuracy: 0.7
880 - val_loss: 0.4519 - val_accuracy: 0.8379
Epoch 2/10
1500/1500 [==============================] - 26s 18ms/step - loss: 0.3858 - accuracy: 0.8
598 - val_loss: 0.3701 - val_accuracy: 0.8677
Epoch 3/10
1500/1500 [==============================] - 25s 17ms/step - loss: 0.3425 - accuracy: 0.8
742 - val_loss: 0.3389 - val_accuracy: 0.8777
Epoch 4/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.3140 - accuracy: 0.8
849 - val_loss: 0.3214 - val_accuracy: 0.8842
Epoch 5/10
1500/1500 [==============================] - 26s 18ms/step - loss: 0.2925 - accuracy: 0.8
912 - val_loss: 0.3079 - val_accuracy: 0.8873
Epoch 6/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.2749 - accuracy: 0.8
981 - val_loss: 0.3273 - val_accuracy: 0.8783
Epoch 7/10
1500/1500 [==============================] - 25s 17ms/step - loss: 0.2610 - accuracy: 0.9
039 - val_loss: 0.2809 - val_accuracy: 0.8983
```

```
Epoch 8/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.2482 - accuracy: 0.9
083 - val_loss: 0.2921 - val_accuracy: 0.8931
Epoch 9/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.2403 - accuracy: 0.9
108 - val_loss: 0.2715 - val_accuracy: 0.8996
Epoch 10/10
1500/1500 [==============================] - 26s 18ms/step - loss: 0.2294 - accuracy: 0.9
147 - val_loss: 0.2821 - val_accuracy: 0.8982
Epoch 1/10
1500/1500 [==============================] - 49s 32ms/step - loss: 0.4939 - accuracy: 0.8
202 - val_loss: 0.3679 - val_accuracy: 0.8621
Epoch 2/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.3238 - accuracy: 0.8
820 - val_loss: 0.3236 - val_accuracy: 0.8830
Epoch 3/10
1500/1500 [==============================] - 50s 33ms/step - loss: 0.2807 - accuracy: 0.8
968 - val_loss: 0.2840 - val_accuracy: 0.8958
Epoch 4/10
1500/1500 [==============================] - 49s 33ms/step - loss: 0.2502 - accuracy: 0.9
087 - val_loss: 0.2736 - val_accuracy: 0.8987
Epoch 5/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2243 - accuracy: 0.9
170 - val_loss: 0.2931 - val_accuracy: 0.8937
Epoch 6/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2070 - accuracy: 0.9
230 - val_loss: 0.2743 - val_accuracy: 0.9017
Epoch 7/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.1913 - accuracy: 0.9
285 - val_loss: 0.2689 - val_accuracy: 0.9058
Epoch 8/10
1500/1500 [==============================] - 49s 33ms/step - loss: 0.1743 - accuracy: 0.9
340 - val_loss: 0.2759 - val_accuracy: 0.9063
Epoch 9/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.1572 - accuracy: 0.9
418 - val_loss: 0.2899 - val_accuracy: 0.9045
Epoch 10/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.1437 - accuracy: 0.9
472 - val_loss: 0.3030 - val_accuracy: 0.9024
Epoch 1/10
1500/1500 [==============================] - 28s 18ms/step - loss: 0.6321 - accuracy: 0.7
727 - val_loss: 0.4711 - val_accuracy: 0.8276
Epoch 2/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.4196 - accuracy: 0.8
470 - val_loss: 0.3941 - val_accuracy: 0.8563
Epoch 3/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.3720 - accuracy: 0.8
625 - val_loss: 0.3696 - val_accuracy: 0.8649
Epoch 4/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.3433 - accuracy: 0.8
742 - val_loss: 0.3725 - val_accuracy: 0.8636
Epoch 5/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.3205 - accuracy: 0.8
800 - val_loss: 0.3611 - val_accuracy: 0.8696
Epoch 6/10
1500/1500 [==============================] - 27s 18ms/step - loss: 0.3049 - accuracy: 0.8
884 - val_loss: 0.3402 - val_accuracy: 0.8741
Epoch 7/10
1500/1500 [==============================] - 28s 18ms/step - loss: 0.2935 - accuracy: 0.8
914 - val_loss: 0.3381 - val_accuracy: 0.8781
Epoch 8/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.2769 - accuracy: 0.8
963 - val_loss: 0.3246 - val_accuracy: 0.8850
Epoch 9/10
1500/1500 [==============================] - 25s 17ms/step - loss: 0.2663 - accuracy: 0.9
002 - val_loss: 0.3164 - val_accuracy: 0.8857
Epoch 10/10
1500/1500 [==============================] - 26s 17ms/step - loss: 0.2566 - accuracy: 0.9
038 - val_loss: 0.3356 - val_accuracy: 0.8877
Epoch 1/10
1500/1500 [==============================] - 49s 32ms/step - loss: 0.4686 - accuracy: 0.8
308 - val_loss: 0.3598 - val_accuracy: 0.8682
```

```
Epoch 2/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.3083 - accuracy: 0.8
863 - val_loss: 0.3102 - val_accuracy: 0.8842
Epoch 3/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2634 - accuracy: 0.9
026 - val_loss: 0.2613 - val_accuracy: 0.9056
Epoch 4/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2311 - accuracy: 0.9
137 - val_loss: 0.2644 - val_accuracy: 0.9001
Epoch 5/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2044 - accuracy: 0.9
241 - val_loss: 0.2593 - val_accuracy: 0.9072
Epoch 6/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.1814 - accuracy: 0.9
327 - val_loss: 0.2561 - val_accuracy: 0.9044
Epoch 7/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.1619 - accuracy: 0.9
395 - val_loss: 0.2441 - val_accuracy: 0.9138
Epoch 8/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.1401 - accuracy: 0.9
474 - val_loss: 0.2661 - val_accuracy: 0.9098
Epoch 9/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.1233 - accuracy: 0.9
543 - val_loss: 0.2750 - val_accuracy: 0.9078
Epoch 10/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.1096 - accuracy: 0.9
584 - val_loss: 0.2771 - val_accuracy: 0.9137
Epoch 1/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.5666 - accuracy: 0.7
976 - val_loss: 0.4134 - val_accuracy: 0.8512
Epoch 2/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.3629 - accuracy: 0.8
683 - val_loss: 0.3533 - val_accuracy: 0.8705
Epoch 3/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.3146 - accuracy: 0.8
863 - val_loss: 0.3132 - val_accuracy: 0.8882
Epoch 4/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.2825 - accuracy: 0.8
969 - val_loss: 0.3122 - val_accuracy: 0.8911
Epoch 5/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2592 - accuracy: 0.9
047 - val_loss: 0.2945 - val_accuracy: 0.8944
Epoch 6/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.2423 - accuracy: 0.9
119 - val_loss: 0.2776 - val_accuracy: 0.8976
Epoch 7/10
1500/1500 [==============================] - 29s 19ms/step - loss: 0.2268 - accuracy: 0.9
158 - val_loss: 0.2757 - val_accuracy: 0.8995
Epoch 8/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.2131 - accuracy: 0.9
218 - val_loss: 0.2733 - val_accuracy: 0.9042
Epoch 9/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.2011 - accuracy: 0.9
258 - val_loss: 0.2618 - val_accuracy: 0.9065
Epoch 10/10
1500/1500 [==============================] - 28s 19ms/step - loss: 0.1893 - accuracy: 0.9
301 - val_loss: 0.2748 - val_accuracy: 0.9060
Epoch 1/10
1500/1500 [==============================] - 70s 46ms/step - loss: 0.4818 - accuracy: 0.8
234 - val_loss: 0.3612 - val_accuracy: 0.8688
Epoch 2/10
1500/1500 [==============================] - 62s 42ms/step - loss: 0.3074 - accuracy: 0.8
880 - val_loss: 0.3170 - val_accuracy: 0.8788
Epoch 3/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.2632 - accuracy: 0.9
035 - val_loss: 0.2677 - val_accuracy: 0.9030
Epoch 4/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.2286 - accuracy: 0.9
156 - val_loss: 0.2601 - val_accuracy: 0.9043
Epoch 5/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.2038 - accuracy: 0.9
244 - val_loss: 0.2671 - val_accuracy: 0.8987
```

```
Epoch 6/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.1811 - accuracy: 0.9
335 - val_loss: 0.2572 - val_accuracy: 0.9085
Epoch 7/10
1500/1500 [==============================] - 62s 42ms/step - loss: 0.1613 - accuracy: 0.9
398 - val_loss: 0.2561 - val_accuracy: 0.9111
Epoch 8/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.1417 - accuracy: 0.9
466 - val_loss: 0.2772 - val_accuracy: 0.9108
Epoch 9/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.1246 - accuracy: 0.9
537 - val_loss: 0.2866 - val_accuracy: 0.9072
Epoch 10/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.1094 - accuracy: 0.9
590 - val_loss: 0.3216 - val_accuracy: 0.9043
Epoch 1/10
1500/1500 [==============================] - 31s 20ms/step - loss: 0.5946 - accuracy: 0.7
826 - val_loss: 0.4274 - val_accuracy: 0.8424
Epoch 2/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.3875 - accuracy: 0.8
595 - val_loss: 0.3646 - val_accuracy: 0.8673
Epoch 3/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.3406 - accuracy: 0.8
756 - val_loss: 0.3325 - val_accuracy: 0.8813
Epoch 4/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.3096 - accuracy: 0.8
858 - val_loss: 0.3304 - val_accuracy: 0.8799
Epoch 5/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2858 - accuracy: 0.8
937 - val_loss: 0.3454 - val_accuracy: 0.8722
Epoch 6/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2692 - accuracy: 0.9
001 - val_loss: 0.3670 - val_accuracy: 0.8741
Epoch 7/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2546 - accuracy: 0.9
062 - val_loss: 0.3077 - val_accuracy: 0.8912
Epoch 8/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2350 - accuracy: 0.9
127 - val_loss: 0.3152 - val_accuracy: 0.8930
Epoch 9/10
1500/1500 [==============================] - 30s 20ms/step - loss: 0.2245 - accuracy: 0.9
158 - val_loss: 0.3024 - val_accuracy: 0.8922
Epoch 10/10
1500/1500 [==============================] - 29s 20ms/step - loss: 0.2131 - accuracy: 0.9
208 - val_loss: 0.3118 - val_accuracy: 0.8948
Epoch 1/10
1500/1500 [==============================] - 42s 28ms/step - loss: 0.4847 - accuracy: 0.8
269 - val_loss: 0.3557 - val_accuracy: 0.8715
Epoch 2/10
1500/1500 [==============================] - 42s 28ms/step - loss: 0.3249 - accuracy: 0.8
834 - val_loss: 0.3138 - val_accuracy: 0.8857
Epoch 3/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.2808 - accuracy: 0.8
970 - val_loss: 0.2815 - val_accuracy: 0.8968
Epoch 4/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.2524 - accuracy: 0.9
071 - val_loss: 0.2698 - val_accuracy: 0.9025
Epoch 5/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.2274 - accuracy: 0.9
158 - val_loss: 0.2684 - val_accuracy: 0.9057
Epoch 6/10
1500/1500 [==============================] - 42s 28ms/step - loss: 0.2077 - accuracy: 0.9
223 - val_loss: 0.2644 - val_accuracy: 0.9055
Epoch 7/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.1922 - accuracy: 0.9
283 - val_loss: 0.2536 - val_accuracy: 0.9102
Epoch 8/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.1752 - accuracy: 0.9
337 - val_loss: 0.2705 - val_accuracy: 0.9048
Epoch 9/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.1584 - accuracy: 0.9
408 - val_loss: 0.2622 - val_accuracy: 0.9083
```

```
Epoch 10/10
1500/1500 [==============================] - 40s 26ms/step - loss: 0.1467 - accuracy: 0.9
439 - val_loss: 0.2650 - val_accuracy: 0.9083
Epoch 1/10
1500/1500 [==============================] - 34s 22ms/step - loss: 0.5968 - accuracy: 0.7
834 - val_loss: 0.4494 - val_accuracy: 0.8373
Epoch 2/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.3976 - accuracy: 0.8
551 - val_loss: 0.3685 - val_accuracy: 0.8662
Epoch 3/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.3441 - accuracy: 0.8
737 - val_loss: 0.3395 - val_accuracy: 0.8765
Epoch 4/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.3100 - accuracy: 0.8
878 - val_loss: 0.3203 - val_accuracy: 0.8823
Epoch 5/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2860 - accuracy: 0.8
942 - val_loss: 0.3260 - val_accuracy: 0.8802
Epoch 6/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2697 - accuracy: 0.9
011 - val_loss: 0.3043 - val_accuracy: 0.8897
Epoch 7/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2572 - accuracy: 0.9
059 - val_loss: 0.2791 - val_accuracy: 0.8976
Epoch 8/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.2423 - accuracy: 0.9
112 - val_loss: 0.2933 - val_accuracy: 0.8936
Epoch 9/10
1500/1500 [==============================] - 32s 22ms/step - loss: 0.2318 - accuracy: 0.9
144 - val_loss: 0.2812 - val_accuracy: 0.8964
Epoch 10/10
1500/1500 [==============================] - 32s 21ms/step - loss: 0.2233 - accuracy: 0.9
170 - val_loss: 0.2725 - val_accuracy: 0.8998
Epoch 1/10
1500/1500 [==============================] - 49s 32ms/step - loss: 0.5089 - accuracy: 0.8
165 - val_loss: 0.3755 - val_accuracy: 0.8642
Epoch 2/10
1500/1500 [==============================] - 50s 33ms/step - loss: 0.3284 - accuracy: 0.8
818 - val_loss: 0.3290 - val_accuracy: 0.8797
Epoch 3/10
1500/1500 [==============================] - 53s 35ms/step - loss: 0.2837 - accuracy: 0.8
965 - val_loss: 0.2876 - val_accuracy: 0.8967
Epoch 4/10
1500/1500 [==============================] - 68s 45ms/step - loss: 0.2552 - accuracy: 0.9
059 - val_loss: 0.2712 - val_accuracy: 0.9007
Epoch 5/10
1500/1500 [==============================] - 53s 36ms/step - loss: 0.2292 - accuracy: 0.9
151 - val_loss: 0.2696 - val_accuracy: 0.9007
Epoch 6/10
1500/1500 [==============================] - 58s 39ms/step - loss: 0.2089 - accuracy: 0.9
220 - val_loss: 0.2567 - val_accuracy: 0.9087
Epoch 7/10
1500/1500 [==============================] - 62s 42ms/step - loss: 0.1893 - accuracy: 0.9
299 - val_loss: 0.2556 - val_accuracy: 0.9082
Epoch 8/10
1500/1500 [==============================] - 64s 42ms/step - loss: 0.1722 - accuracy: 0.9
350 - val_loss: 0.2691 - val_accuracy: 0.9061
Epoch 9/10
1500/1500 [==============================] - 52s 35ms/step - loss: 0.1562 - accuracy: 0.9
418 - val_loss: 0.2569 - val_accuracy: 0.9137
Epoch 10/10
1500/1500 [==============================] - 50s 33ms/step - loss: 0.1428 - accuracy: 0.9
474 - val_loss: 0.2782 - val_accuracy: 0.9055
Epoch 1/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.6094 - accuracy: 0.7
809 - val_loss: 0.4448 - val_accuracy: 0.8403
Epoch 2/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.3993 - accuracy: 0.8
557 - val_loss: 0.3702 - val_accuracy: 0.8670
Epoch 3/10
1500/1500 [==============================] - 38s 26ms/step - loss: 0.3545 - accuracy: 0.8
713 - val_loss: 0.3442 - val_accuracy: 0.8790
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Epoch 4/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.3219 - accuracy: 0.8
822 - val_loss: 0.3437 - val_accuracy: 0.8729
Epoch 5/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2992 - accuracy: 0.8
906 - val_loss: 0.3731 - val_accuracy: 0.8662
Epoch 6/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2814 - accuracy: 0.8
967 - val_loss: 0.3393 - val_accuracy: 0.8793
Epoch 7/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2682 - accuracy: 0.9
009 - val_loss: 0.3127 - val_accuracy: 0.8871
Epoch 8/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.2527 - accuracy: 0.9
065 - val_loss: 0.3034 - val_accuracy: 0.8935
Epoch 9/10
1500/1500 [==============================] - 33s 22ms/step - loss: 0.2414 - accuracy: 0.9
112 - val_loss: 0.2918 - val_accuracy: 0.8921
Epoch 10/10
1500/1500 [==============================] - 34s 22ms/step - loss: 0.2299 - accuracy: 0.9
150 - val_loss: 0.3049 - val_accuracy: 0.8920
Epoch 1/10
1500/1500 [==============================] - 54s 35ms/step - loss: 0.4794 - accuracy: 0.8
261 - val_loss: 0.3521 - val_accuracy: 0.8733
Epoch 2/10
1500/1500 [==============================] - 51s 34ms/step - loss: 0.3109 - accuracy: 0.8
869 - val_loss: 0.2976 - val_accuracy: 0.8913
Epoch 3/10
1500/1500 [==============================] - 52s 35ms/step - loss: 0.2640 - accuracy: 0.9
035 - val_loss: 0.2626 - val_accuracy: 0.9036
Epoch 4/10
1500/1500 [==============================] - 50s 33ms/step - loss: 0.2315 - accuracy: 0.9
152 - val_loss: 0.2583 - val_accuracy: 0.9050
Epoch 5/10
1500/1500 [==============================] - 50s 33ms/step - loss: 0.2057 - accuracy: 0.9
230 - val_loss: 0.2627 - val_accuracy: 0.9075
Epoch 6/10
1500/1500 [==============================] - 52s 35ms/step - loss: 0.1832 - accuracy: 0.9
310 - val_loss: 0.2415 - val_accuracy: 0.9118
Epoch 7/10
1500/1500 [==============================] - 50s 33ms/step - loss: 0.1632 - accuracy: 0.9
390 - val_loss: 0.2493 - val_accuracy: 0.9144
Epoch 8/10
1500/1500 [==============================] - 51s 34ms/step - loss: 0.1433 - accuracy: 0.9
460 - val_loss: 0.2557 - val_accuracy: 0.9135
Epoch 9/10
1500/1500 [==============================] - 52s 34ms/step - loss: 0.1269 - accuracy: 0.9
516 - val_loss: 0.2682 - val_accuracy: 0.9126
Epoch 10/10
1500/1500 [==============================] - 50s 33ms/step - loss: 0.1128 - accuracy: 0.9
566 - val_loss: 0.2810 - val_accuracy: 0.9137
Epoch 1/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.5551 - accuracy: 0.8
006 - val_loss: 0.4202 - val_accuracy: 0.8505
Epoch 2/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.3615 - accuracy: 0.8
685 - val_loss: 0.3455 - val_accuracy: 0.8733
Epoch 3/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.3152 - accuracy: 0.8
848 - val_loss: 0.3042 - val_accuracy: 0.8907
Epoch 4/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.2849 - accuracy: 0.8
953 - val_loss: 0.2960 - val_accuracy: 0.8915
Epoch 5/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.2625 - accuracy: 0.9
029 - val_loss: 0.3175 - val_accuracy: 0.8844
Epoch 6/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.2447 - accuracy: 0.9
104 - val_loss: 0.2812 - val_accuracy: 0.8962
Epoch 7/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.2296 - accuracy: 0.9
147 - val_loss: 0.2681 - val_accuracy: 0.9013
```

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Epoch 8/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.2135 - accuracy: 0.9
212 - val_loss: 0.2623 - val_accuracy: 0.9058
Epoch 9/10
1500/1500 [==============================] - 37s 24ms/step - loss: 0.2039 - accuracy: 0.9
243 - val_loss: 0.2642 - val_accuracy: 0.9030
Epoch 10/10
1500/1500 [==============================] - 35s 23ms/step - loss: 0.1934 - accuracy: 0.9
278 - val_loss: 0.2713 - val_accuracy: 0.9045
Epoch 1/10
1500/1500 [==============================] - 63s 41ms/step - loss: 0.4679 - accuracy: 0.8
294 - val_loss: 0.3432 - val_accuracy: 0.8734
Epoch 2/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.3060 - accuracy: 0.8
887 - val_loss: 0.2992 - val_accuracy: 0.8873
Epoch 3/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.2650 - accuracy: 0.9
019 - val_loss: 0.2734 - val_accuracy: 0.9022
Epoch 4/10
1500/1500 [==============================] - 61s 40ms/step - loss: 0.2335 - accuracy: 0.9
136 - val_loss: 0.2771 - val_accuracy: 0.9038
Epoch 5/10
1500/1500 [==============================] - 60s 40ms/step - loss: 0.2071 - accuracy: 0.9
220 - val_loss: 0.2694 - val_accuracy: 0.9061
Epoch 6/10
1500/1500 [==============================] - 61s 40ms/step - loss: 0.1877 - accuracy: 0.9
298 - val_loss: 0.2592 - val_accuracy: 0.9078
Epoch 7/10
1500/1500 [==============================] - 61s 40ms/step - loss: 0.1682 - accuracy: 0.9
370 - val_loss: 0.2551 - val_accuracy: 0.9089
Epoch 8/10
1500/1500 [==============================] - 61s 41ms/step - loss: 0.1517 - accuracy: 0.9
427 - val_loss: 0.2641 - val_accuracy: 0.9116
Epoch 9/10
1500/1500 [==============================] - 60s 40ms/step - loss: 0.1330 - accuracy: 0.9
502 - val_loss: 0.2823 - val_accuracy: 0.9094
Epoch 10/10
1500/1500 [==============================] - 61s 41ms/step - loss: 0.1201 - accuracy: 0.9
545 - val_loss: 0.3008 - val_accuracy: 0.9078
Epoch 1/10
1500/1500 [==============================] - 37s 24ms/step - loss: 0.6043 - accuracy: 0.7
781 - val_loss: 0.4412 - val_accuracy: 0.8402
Epoch 2/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.3968 - accuracy: 0.8
562 - val_loss: 0.3705 - val_accuracy: 0.8662
Epoch 3/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.3456 - accuracy: 0.8
730 - val_loss: 0.3487 - val_accuracy: 0.8771
Epoch 4/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.3118 - accuracy: 0.8
857 - val_loss: 0.3397 - val_accuracy: 0.8759
Epoch 5/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.2876 - accuracy: 0.8
933 - val_loss: 0.3602 - val_accuracy: 0.8658
Epoch 6/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.2697 - accuracy: 0.9
004 - val_loss: 0.3137 - val_accuracy: 0.8844
Epoch 7/10
1500/1500 [==============================] - 37s 25ms/step - loss: 0.2529 - accuracy: 0.9
063 - val_loss: 0.3009 - val_accuracy: 0.8911
Epoch 8/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.2352 - accuracy: 0.9
118 - val_loss: 0.2963 - val_accuracy: 0.8954
Epoch 9/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.2215 - accuracy: 0.9
181 - val_loss: 0.2896 - val_accuracy: 0.8965
Epoch 10/10
1500/1500 [==============================] - 36s 24ms/step - loss: 0.2083 - accuracy: 0.9
223 - val_loss: 0.2906 - val_accuracy: 0.8966
Epoch 1/10
1500/1500 [==============================] - 65s 43ms/step - loss: 0.4921 - accuracy: 0.8
210 - val_loss: 0.3671 - val_accuracy: 0.8648
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Epoch 2/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.3243 - accuracy: 0.8
814 - val_loss: 0.3208 - val_accuracy: 0.8783
Epoch 3/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.2810 - accuracy: 0.8
966 - val_loss: 0.2749 - val_accuracy: 0.8982
Epoch 4/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.2515 - accuracy: 0.9
067 - val_loss: 0.2711 - val_accuracy: 0.8976
Epoch 5/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.2272 - accuracy: 0.9
143 - val_loss: 0.2673 - val_accuracy: 0.9019
Epoch 6/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.2075 - accuracy: 0.9
232 - val_loss: 0.2560 - val_accuracy: 0.9064
Epoch 7/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.1904 - accuracy: 0.9
284 - val_loss: 0.2540 - val_accuracy: 0.9093
Epoch 8/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.1698 - accuracy: 0.9
360 - val_loss: 0.2592 - val_accuracy: 0.9093
Epoch 9/10
1500/1500 [==============================] - 62s 41ms/step - loss: 0.1545 - accuracy: 0.9
414 - val_loss: 0.2625 - val_accuracy: 0.9102
Epoch 10/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.1418 - accuracy: 0.9
461 - val_loss: 0.2689 - val_accuracy: 0.9095
Epoch 1/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.5666 - accuracy: 0.7
966 - val_loss: 0.4253 - val_accuracy: 0.8468
Epoch 2/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.3734 - accuracy: 0.8
635 - val_loss: 0.3606 - val_accuracy: 0.8672
Epoch 3/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.3257 - accuracy: 0.8
805 - val_loss: 0.3260 - val_accuracy: 0.8839
Epoch 4/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.2973 - accuracy: 0.8
913 - val_loss: 0.3097 - val_accuracy: 0.8850
Epoch 5/10
1500/1500 [==============================] - 40s 26ms/step - loss: 0.2769 - accuracy: 0.8
982 - val_loss: 0.3026 - val_accuracy: 0.8883
Epoch 6/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.2607 - accuracy: 0.9
032 - val_loss: 0.3061 - val_accuracy: 0.8876
Epoch 7/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.2480 - accuracy: 0.9
080 - val_loss: 0.2886 - val_accuracy: 0.8955
Epoch 8/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.2334 - accuracy: 0.9
125 - val_loss: 0.2942 - val_accuracy: 0.8942
Epoch 9/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.2234 - accuracy: 0.9
166 - val_loss: 0.2788 - val_accuracy: 0.8997
Epoch 10/10
1500/1500 [==============================] - 41s 27ms/step - loss: 0.2143 - accuracy: 0.9
195 - val_loss: 0.2892 - val_accuracy: 0.8971
Epoch 1/10
1500/1500 [==============================] - 83s 55ms/step - loss: 0.4997 - accuracy: 0.8
190 - val_loss: 0.3733 - val_accuracy: 0.8630
Epoch 2/10
1500/1500 [==============================] - 82s 55ms/step - loss: 0.3254 - accuracy: 0.8
811 - val_loss: 0.3300 - val_accuracy: 0.8783
Epoch 3/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.2812 - accuracy: 0.8
961 - val_loss: 0.2782 - val_accuracy: 0.9001
Epoch 4/10
1500/1500 [==============================] - 80s 53ms/step - loss: 0.2510 - accuracy: 0.9
080 - val_loss: 0.2787 - val_accuracy: 0.8975
Epoch 5/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.2267 - accuracy: 0.9
172 - val_loss: 0.2801 - val_accuracy: 0.9003
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Epoch 6/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.2093 - accuracy: 0.9
226 - val_loss: 0.2717 - val_accuracy: 0.9005
Epoch 7/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.1903 - accuracy: 0.9
305 - val_loss: 0.2617 - val_accuracy: 0.9043
Epoch 8/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.1717 - accuracy: 0.9
351 - val_loss: 0.2763 - val_accuracy: 0.9051
Epoch 9/10
1500/1500 [==============================] - 87s 58ms/step - loss: 0.1565 - accuracy: 0.9
409 - val_loss: 0.2828 - val_accuracy: 0.9062
Epoch 10/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.1435 - accuracy: 0.9
460 - val_loss: 0.2773 - val_accuracy: 0.9037
Epoch 1/10
1500/1500 [==============================] - 44s 29ms/step - loss: 0.6004 - accuracy: 0.7
807 - val_loss: 0.4527 - val_accuracy: 0.8349
Epoch 2/10
1500/1500 [==============================] - 40s 26ms/step - loss: 0.3969 - accuracy: 0.8
550 - val_loss: 0.3699 - val_accuracy: 0.8679
Epoch 3/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.3517 - accuracy: 0.8
709 - val_loss: 0.3442 - val_accuracy: 0.8763
Epoch 4/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.3247 - accuracy: 0.8
801 - val_loss: 0.3403 - val_accuracy: 0.8772
Epoch 5/10
1500/1500 [==============================] - 38s 26ms/step - loss: 0.3021 - accuracy: 0.8
889 - val_loss: 0.3560 - val_accuracy: 0.8714
Epoch 6/10
1500/1500 [==============================] - 40s 27ms/step - loss: 0.2874 - accuracy: 0.8
931 - val_loss: 0.3499 - val_accuracy: 0.8748
Epoch 7/10
1500/1500 [==============================] - 38s 26ms/step - loss: 0.2742 - accuracy: 0.8
985 - val_loss: 0.3241 - val_accuracy: 0.8844
Epoch 8/10
1500/1500 [==============================] - 40s 26ms/step - loss: 0.2575 - accuracy: 0.9
040 - val_loss: 0.3193 - val_accuracy: 0.8882
Epoch 9/10
1500/1500 [==============================] - 39s 26ms/step - loss: 0.2463 - accuracy: 0.9
095 - val_loss: 0.3101 - val_accuracy: 0.8895
Epoch 10/10
1500/1500 [==============================] - 38s 25ms/step - loss: 0.2345 - accuracy: 0.9
133 - val_loss: 0.3181 - val_accuracy: 0.8913
Epoch 1/10
1500/1500 [==============================] - 80s 53ms/step - loss: 0.4595 - accuracy: 0.8
328 - val_loss: 0.3475 - val_accuracy: 0.8714
Epoch 2/10
1500/1500 [==============================] - 77s 51ms/step - loss: 0.3064 - accuracy: 0.8
864 - val_loss: 0.2934 - val_accuracy: 0.8917
Epoch 3/10
1500/1500 [==============================] - 77s 51ms/step - loss: 0.2618 - accuracy: 0.9
035 - val_loss: 0.2590 - val_accuracy: 0.9047
Epoch 4/10
1500/1500 [==============================] - 76s 51ms/step - loss: 0.2274 - accuracy: 0.9
150 - val_loss: 0.2563 - val_accuracy: 0.9041
Epoch 5/10
1500/1500 [==============================] - 77s 52ms/step - loss: 0.2001 - accuracy: 0.9
256 - val_loss: 0.2652 - val_accuracy: 0.9039
Epoch 6/10
1500/1500 [==============================] - 76s 51ms/step - loss: 0.1787 - accuracy: 0.9
331 - val_loss: 0.2440 - val_accuracy: 0.9097
Epoch 7/10
1500/1500 [==============================] - 77s 51ms/step - loss: 0.1563 - accuracy: 0.9
420 - val_loss: 0.2389 - val_accuracy: 0.9122
Epoch 8/10
1500/1500 [==============================] - 77s 51ms/step - loss: 0.1370 - accuracy: 0.9
483 - val_loss: 0.2647 - val_accuracy: 0.9135
Epoch 9/10
1500/1500 [==============================] - 77s 52ms/step - loss: 0.1190 - accuracy: 0.9
554 - val_loss: 0.2725 - val_accuracy: 0.9086
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Epoch 10/10
1500/1500 [==============================] - 76s 51ms/step - loss: 0.1075 - accuracy: 0.9
590 - val_loss: 0.2714 - val_accuracy: 0.9120
Epoch 1/10
1500/1500 [==============================] - 46s 30ms/step - loss: 0.5474 - accuracy: 0.8
042 - val_loss: 0.4185 - val_accuracy: 0.8483
Epoch 2/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.3506 - accuracy: 0.8
723 - val_loss: 0.3351 - val_accuracy: 0.8757
Epoch 3/10
1500/1500 [==============================] - 46s 30ms/step - loss: 0.3056 - accuracy: 0.8
892 - val_loss: 0.2977 - val_accuracy: 0.8910
Epoch 4/10
1500/1500 [==============================] - 44s 29ms/step - loss: 0.2762 - accuracy: 0.8
988 - val_loss: 0.3085 - val_accuracy: 0.8866
Epoch 5/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.2559 - accuracy: 0.9
059 - val_loss: 0.2944 - val_accuracy: 0.8928
Epoch 6/10
1500/1500 [==============================] - 43s 29ms/step - loss: 0.2364 - accuracy: 0.9
130 - val_loss: 0.2972 - val_accuracy: 0.8932
Epoch 7/10
1500/1500 [==============================] - 45s 30ms/step - loss: 0.2232 - accuracy: 0.9
176 - val_loss: 0.2640 - val_accuracy: 0.9044
Epoch 8/10
1500/1500 [==============================] - 44s 30ms/step - loss: 0.2081 - accuracy: 0.9
226 - val_loss: 0.2676 - val_accuracy: 0.9040
Epoch 9/10
1500/1500 [==============================] - 43s 29ms/step - loss: 0.1952 - accuracy: 0.9
278 - val_loss: 0.2672 - val_accuracy: 0.9029
Epoch 10/10
1500/1500 [==============================] - 42s 28ms/step - loss: 0.1845 - accuracy: 0.9
310 - val_loss: 0.2671 - val_accuracy: 0.9057
Epoch 1/10
1500/1500 [==============================] - 116s 77ms/step - loss: 0.4832 - accuracy: 0.
8221 - val_loss: 0.3467 - val_accuracy: 0.8740
Epoch 2/10
1500/1500 [==============================] - 114s 76ms/step - loss: 0.3079 - accuracy: 0.
8863 - val_loss: 0.3097 - val_accuracy: 0.8849
Epoch 3/10
1500/1500 [==============================] - 118s 78ms/step - loss: 0.2631 - accuracy: 0.
9030 - val_loss: 0.2690 - val_accuracy: 0.9019
Epoch 4/10
1500/1500 [==============================] - 117s 78ms/step - loss: 0.2287 - accuracy: 0.
9162 - val_loss: 0.2587 - val_accuracy: 0.9054
Epoch 5/10
1500/1500 [==============================] - 114s 76ms/step - loss: 0.2014 - accuracy: 0.
9237 - val_loss: 0.2874 - val_accuracy: 0.8990
Epoch 6/10
1500/1500 [==============================] - 118s 79ms/step - loss: 0.1768 - accuracy: 0.
9336 - val_loss: 0.2595 - val_accuracy: 0.9055
Epoch 7/10
1500/1500 [==============================] - 113s 76ms/step - loss: 0.1576 - accuracy: 0.
9419 - val_loss: 0.2537 - val_accuracy: 0.9118
Epoch 8/10
1500/1500 [==============================] - 118s 79ms/step - loss: 0.1387 - accuracy: 0.
9476 - val_loss: 0.2943 - val_accuracy: 0.9047
Epoch 9/10
1500/1500 [==============================] - 115s 77ms/step - loss: 0.1217 - accuracy: 0.
9538 - val_loss: 0.2886 - val_accuracy: 0.9097
Epoch 10/10
1500/1500 [==============================] - 118s 78ms/step - loss: 0.1066 - accuracy: 0.
9595 - val_loss: 0.2970 - val_accuracy: 0.9070
Epoch 1/10
1500/1500 [==============================] - 50s 32ms/step - loss: 0.5746 - accuracy: 0.7
907 - val_loss: 0.4258 - val_accuracy: 0.8432
Epoch 2/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.3795 - accuracy: 0.8
625 - val_loss: 0.3534 - val_accuracy: 0.8707
Epoch 3/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.3315 - accuracy: 0.8
791 - val_loss: 0.3252 - val_accuracy: 0.8847
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Epoch 4/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.3000 - accuracy: 0.8
899 - val_loss: 0.3391 - val_accuracy: 0.8769
Epoch 5/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2765 - accuracy: 0.8
979 - val_loss: 0.3360 - val_accuracy: 0.8799
Epoch 6/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2575 - accuracy: 0.9
045 - val_loss: 0.3340 - val_accuracy: 0.8815
Epoch 7/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2419 - accuracy: 0.9
096 - val_loss: 0.3020 - val_accuracy: 0.8923
Epoch 8/10
1500/1500 [==============================] - 49s 33ms/step - loss: 0.2241 - accuracy: 0.9
170 - val_loss: 0.3064 - val_accuracy: 0.8928
Epoch 9/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2104 - accuracy: 0.9
219 - val_loss: 0.3078 - val_accuracy: 0.8913
Epoch 10/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.1949 - accuracy: 0.9
280 - val_loss: 0.3133 - val_accuracy: 0.8947
Epoch 1/10
1500/1500 [==============================] - 65s 43ms/step - loss: 0.4888 - accuracy: 0.8
229 - val_loss: 0.3798 - val_accuracy: 0.8627
Epoch 2/10
1500/1500 [==============================] - 66s 44ms/step - loss: 0.3250 - accuracy: 0.8
813 - val_loss: 0.3120 - val_accuracy: 0.8851
Epoch 3/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.2789 - accuracy: 0.8
973 - val_loss: 0.2826 - val_accuracy: 0.8961
Epoch 4/10
1500/1500 [==============================] - 64s 43ms/step - loss: 0.2489 - accuracy: 0.9
079 - val_loss: 0.2725 - val_accuracy: 0.8993
Epoch 5/10
1500/1500 [==============================] - 64s 43ms/step - loss: 0.2253 - accuracy: 0.9
163 - val_loss: 0.2642 - val_accuracy: 0.9067
Epoch 6/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.2051 - accuracy: 0.9
241 - val_loss: 0.2522 - val_accuracy: 0.9054
Epoch 7/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.1889 - accuracy: 0.9
292 - val_loss: 0.2431 - val_accuracy: 0.9130
Epoch 8/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.1695 - accuracy: 0.9
362 - val_loss: 0.2612 - val_accuracy: 0.9121
Epoch 9/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.1556 - accuracy: 0.9
432 - val_loss: 0.2723 - val_accuracy: 0.9072
Epoch 10/10
1500/1500 [==============================] - 63s 42ms/step - loss: 0.1415 - accuracy: 0.9
475 - val_loss: 0.2698 - val_accuracy: 0.9070
Epoch 1/10
1500/1500 [==============================] - 51s 33ms/step - loss: 0.5522 - accuracy: 0.8
009 - val_loss: 0.4057 - val_accuracy: 0.8546
Epoch 2/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.3511 - accuracy: 0.8
734 - val_loss: 0.3261 - val_accuracy: 0.8798
Epoch 3/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.3055 - accuracy: 0.8
899 - val_loss: 0.2985 - val_accuracy: 0.8927
Epoch 4/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2785 - accuracy: 0.8
981 - val_loss: 0.2991 - val_accuracy: 0.8914
Epoch 5/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2562 - accuracy: 0.9
053 - val_loss: 0.3122 - val_accuracy: 0.8867
Epoch 6/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2418 - accuracy: 0.9
122 - val_loss: 0.2760 - val_accuracy: 0.9000
Epoch 7/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2274 - accuracy: 0.9
171 - val_loss: 0.2621 - val_accuracy: 0.9040
```

```
Epoch 8/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.2146 - accuracy: 0.9
208 - val_loss: 0.2533 - val_accuracy: 0.9088
Epoch 9/10
1500/1500 [==============================] - 47s 31ms/step - loss: 0.2042 - accuracy: 0.9
245 - val_loss: 0.2564 - val_accuracy: 0.9071
Epoch 10/10
1500/1500 [==============================] - 46s 31ms/step - loss: 0.1947 - accuracy: 0.9
274 - val_loss: 0.2693 - val_accuracy: 0.9040
Epoch 1/10
1500/1500 [==============================] - 81s 53ms/step - loss: 0.4999 - accuracy: 0.8
201 - val_loss: 0.3833 - val_accuracy: 0.8600
Epoch 2/10
1500/1500 [==============================] - 84s 56ms/step - loss: 0.3223 - accuracy: 0.8
815 - val_loss: 0.3249 - val_accuracy: 0.8810
Epoch 3/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.2789 - accuracy: 0.8
968 - val_loss: 0.2729 - val_accuracy: 0.9014
Epoch 4/10
1500/1500 [==============================] - 84s 56ms/step - loss: 0.2496 - accuracy: 0.9
074 - val_loss: 0.2738 - val_accuracy: 0.8992
Epoch 5/10
1500/1500 [==============================] - 79s 53ms/step - loss: 0.2253 - accuracy: 0.9
156 - val_loss: 0.2625 - val_accuracy: 0.9031
Epoch 6/10
1500/1500 [==============================] - 80s 54ms/step - loss: 0.2076 - accuracy: 0.9
221 - val_loss: 0.2564 - val_accuracy: 0.9077
Epoch 7/10
1500/1500 [==============================] - 80s 54ms/step - loss: 0.1891 - accuracy: 0.9
294 - val_loss: 0.2600 - val_accuracy: 0.9087
Epoch 8/10
1500/1500 [==============================] - 79s 53ms/step - loss: 0.1729 - accuracy: 0.9
344 - val_loss: 0.2619 - val_accuracy: 0.9074
Epoch 9/10
1500/1500 [==============================] - 81s 54ms/step - loss: 0.1565 - accuracy: 0.9
417 - val_loss: 0.2740 - val_accuracy: 0.9077
Epoch 10/10
1500/1500 [==============================] - 79s 53ms/step - loss: 0.1456 - accuracy: 0.9
446 - val_loss: 0.2661 - val_accuracy: 0.9118
Epoch 1/10
1500/1500 [==============================] - 51s 33ms/step - loss: 0.6125 - accuracy: 0.7
738 - val_loss: 0.4642 - val_accuracy: 0.8274
Epoch 2/10
1500/1500 [==============================] - 52s 35ms/step - loss: 0.3993 - accuracy: 0.8
532 - val_loss: 0.3747 - val_accuracy: 0.8627
Epoch 3/10
1500/1500 [==============================] - 49s 33ms/step - loss: 0.3465 - accuracy: 0.8
730 - val_loss: 0.3397 - val_accuracy: 0.8763
Epoch 4/10
1500/1500 [==============================] - 49s 32ms/step - loss: 0.3160 - accuracy: 0.8
843 - val_loss: 0.3393 - val_accuracy: 0.8773
Epoch 5/10
1500/1500 [==============================] - 49s 32ms/step - loss: 0.2928 - accuracy: 0.8
919 - val_loss: 0.3289 - val_accuracy: 0.8806
Epoch 6/10
1500/1500 [==============================] - 51s 34ms/step - loss: 0.2752 - accuracy: 0.8
978 - val_loss: 0.3161 - val_accuracy: 0.8867
Epoch 7/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.2598 - accuracy: 0.9
039 - val_loss: 0.3140 - val_accuracy: 0.8873
Epoch 8/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.2450 - accuracy: 0.9
091 - val_loss: 0.2932 - val_accuracy: 0.8978
Epoch 9/10
1500/1500 [==============================] - 48s 32ms/step - loss: 0.2323 - accuracy: 0.9
143 - val_loss: 0.3060 - val_accuracy: 0.8882
Epoch 10/10
1500/1500 [==============================] - 51s 34ms/step - loss: 0.2206 - accuracy: 0.9
185 - val_loss: 0.2947 - val_accuracy: 0.8967
Epoch 1/10
1500/1500 [==============================] - 82s 54ms/step - loss: 0.4667 - accuracy: 0.8
311 - val_loss: 0.3557 - val_accuracy: 0.8714
```

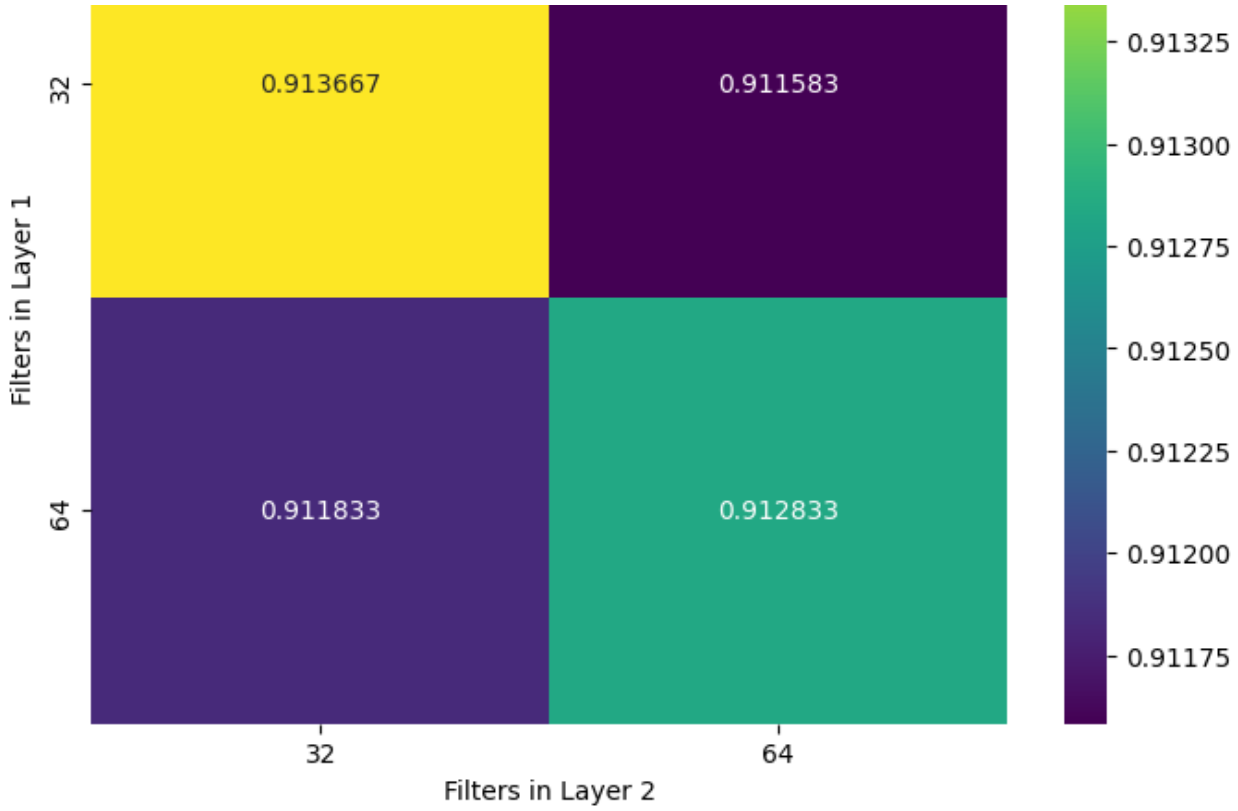
```
Epoch 2/10
1500/1500 [==============================] - 80s 53ms/step - loss: 0.3060 - accuracy: 0.8
886 - val_loss: 0.2921 - val_accuracy: 0.8898
Epoch 3/10
1500/1500 [==============================] - 78s 52ms/step - loss: 0.2619 - accuracy: 0.9
049 - val_loss: 0.2711 - val_accuracy: 0.9011
Epoch 4/10
1500/1500 [==============================] - 78s 52ms/step - loss: 0.2294 - accuracy: 0.9
159 - val_loss: 0.2578 - val_accuracy: 0.9049
Epoch 5/10
1500/1500 [==============================] - 79s 53ms/step - loss: 0.2042 - accuracy: 0.9
241 - val_loss: 0.2485 - val_accuracy: 0.9069
Epoch 6/10
1500/1500 [==============================] - 77s 52ms/step - loss: 0.1807 - accuracy: 0.9
322 - val_loss: 0.2477 - val_accuracy: 0.9112
Epoch 7/10
1500/1500 [==============================] - 77s 51ms/step - loss: 0.1620 - accuracy: 0.9
399 - val_loss: 0.2472 - val_accuracy: 0.9122
Epoch 8/10
1500/1500 [==============================] - 77s 51ms/step - loss: 0.1426 - accuracy: 0.9
466 - val_loss: 0.2718 - val_accuracy: 0.9133
Epoch 9/10
1500/1500 [==============================] - 78s 52ms/step - loss: 0.1254 - accuracy: 0.9
537 - val_loss: 0.2868 - val_accuracy: 0.9081
Epoch 10/10
1500/1500 [==============================] - 78s 52ms/step - loss: 0.1114 - accuracy: 0.9
571 - val_loss: 0.2895 - val_accuracy: 0.9100
Epoch 1/10
1500/1500 [==============================] - 55s 36ms/step - loss: 0.5249 - accuracy: 0.8
123 - val_loss: 0.3912 - val_accuracy: 0.8583
Epoch 2/10
1500/1500 [==============================] - 55s 37ms/step - loss: 0.3355 - accuracy: 0.8
795 - val_loss: 0.3135 - val_accuracy: 0.8851
Epoch 3/10
1500/1500 [==============================] - 52s 35ms/step - loss: 0.2930 - accuracy: 0.8
945 - val_loss: 0.2968 - val_accuracy: 0.8938
Epoch 4/10
1500/1500 [==============================] - 55s 36ms/step - loss: 0.2647 - accuracy: 0.9
043 - val_loss: 0.2861 - val_accuracy: 0.8983
Epoch 5/10
1500/1500 [==============================] - 55s 36ms/step - loss: 0.2413 - accuracy: 0.9
117 - val_loss: 0.2926 - val_accuracy: 0.8924
Epoch 6/10
1500/1500 [==============================] - 54s 36ms/step - loss: 0.2250 - accuracy: 0.9
179 - val_loss: 0.2943 - val_accuracy: 0.8926
Epoch 7/10
1500/1500 [==============================] - 54s 36ms/step - loss: 0.2103 - accuracy: 0.9
219 - val_loss: 0.2540 - val_accuracy: 0.9067
Epoch 8/10
1500/1500 [==============================] - 54s 36ms/step - loss: 0.1941 - accuracy: 0.9
290 - val_loss: 0.2552 - val_accuracy: 0.9102
Epoch 9/10
1500/1500 [==============================] - 52s 35ms/step - loss: 0.1827 - accuracy: 0.9
332 - val_loss: 0.2609 - val_accuracy: 0.9081
Epoch 10/10
1500/1500 [==============================] - 53s 35ms/step - loss: 0.1702 - accuracy: 0.9
374 - val_loss: 0.2532 - val_accuracy: 0.9112
Epoch 1/10
1500/1500 [==============================] - 118s 78ms/step - loss: 0.4677 - accuracy: 0.
8314 - val_loss: 0.3425 - val_accuracy: 0.8731
Epoch 2/10
1500/1500 [==============================] - 115s 77ms/step - loss: 0.3050 - accuracy: 0.
8885 - val_loss: 0.3085 - val_accuracy: 0.8863
Epoch 3/10
1500/1500 [==============================] - 111s 74ms/step - loss: 0.2633 - accuracy: 0.
9036 - val_loss: 0.2691 - val_accuracy: 0.9018
Epoch 4/10
1500/1500 [==============================] - 111s 74ms/step - loss: 0.2309 - accuracy: 0.
9142 - val_loss: 0.2601 - val_accuracy: 0.9065
Epoch 5/10
1500/1500 [==============================] - 115s 77ms/step - loss: 0.2050 - accuracy: 0.
9243 - val_loss: 0.2626 - val_accuracy: 0.9078
```

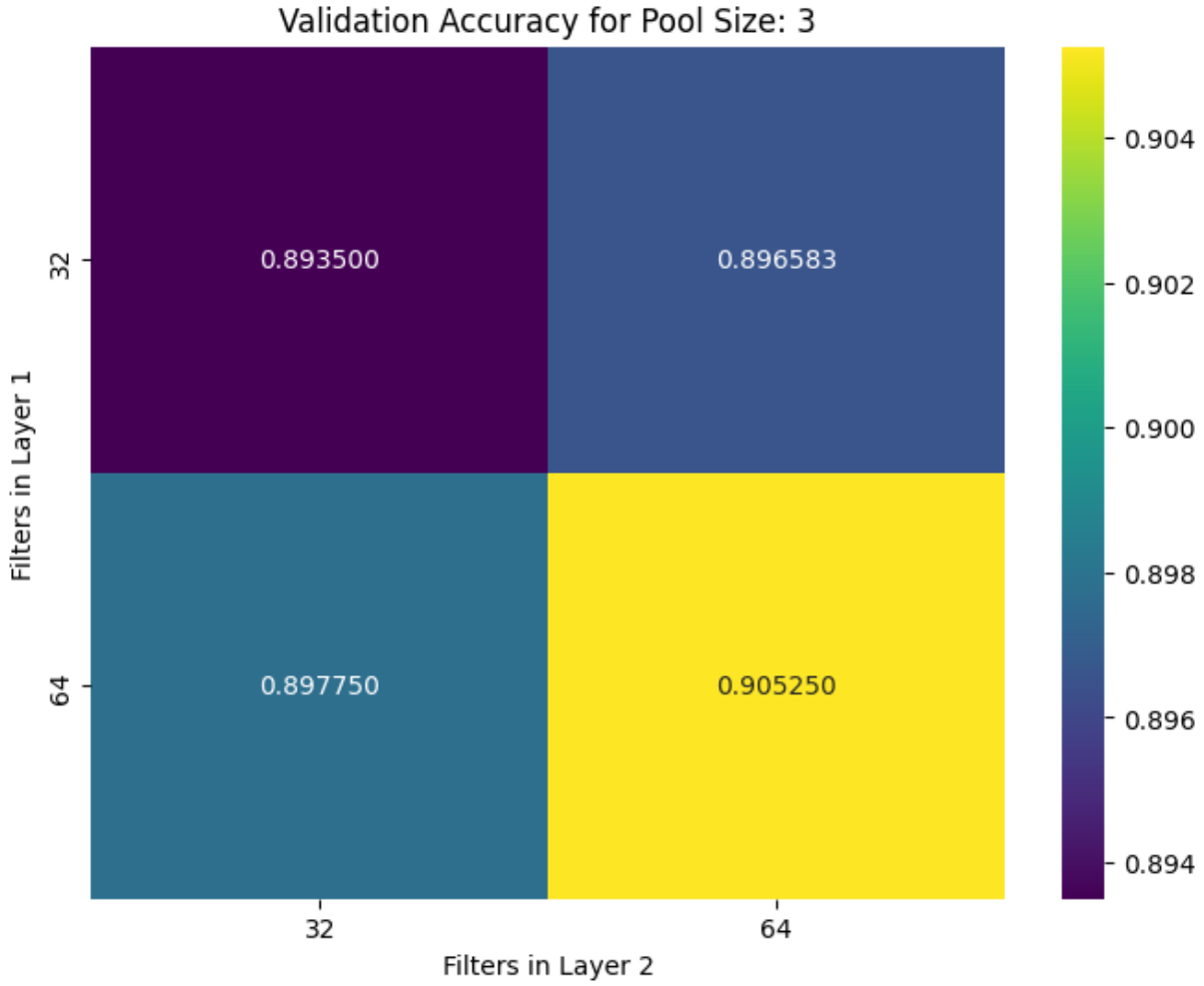
```
Epoch 6/10
1500/1500 [==============================] - 110s 74ms/step - loss: 0.1833 - accuracy: 0.
9319 - val_loss: 0.2523 - val_accuracy: 0.9078
Epoch 7/10
1500/1500 [==============================] - 111s 74ms/step - loss: 0.1631 - accuracy: 0.
9391 - val_loss: 0.2521 - val_accuracy: 0.9128
Epoch 8/10
1500/1500 [==============================] - 115s 77ms/step - loss: 0.1451 - accuracy: 0.
9452 - val_loss: 0.2804 - val_accuracy: 0.9107
Epoch 9/10
1500/1500 [==============================] - 111s 74ms/step - loss: 0.1308 - accuracy: 0.
9516 - val_loss: 0.2841 - val_accuracy: 0.9117
Epoch 10/10
1500/1500 [==============================] - 115s 77ms/step - loss: 0.1135 - accuracy: 0.
9563 - val_loss: 0.2948 - val_accuracy: 0.9076
Epoch 1/10
1500/1500 [==============================] - 59s 39ms/step - loss: 0.5645 - accuracy: 0.7
950 - val_loss: 0.4192 - val_accuracy: 0.8472
Epoch 2/10
1500/1500 [==============================] - 56s 37ms/step - loss: 0.3624 - accuracy: 0.8
686 - val_loss: 0.3371 - val_accuracy: 0.8769
Epoch 3/10
1500/1500 [==============================] - 57s 38ms/step - loss: 0.3150 - accuracy: 0.8
851 - val_loss: 0.3115 - val_accuracy: 0.8887
Epoch 4/10
1500/1500 [==============================] - 55s 37ms/step - loss: 0.2842 - accuracy: 0.8
959 - val_loss: 0.3194 - val_accuracy: 0.8869
Epoch 5/10
1500/1500 [==============================] - 57s 38ms/step - loss: 0.2585 - accuracy: 0.9
063 - val_loss: 0.3175 - val_accuracy: 0.8876
Epoch 6/10
1500/1500 [==============================] - 57s 38ms/step - loss: 0.2424 - accuracy: 0.9
099 - val_loss: 0.3339 - val_accuracy: 0.8829
Epoch 7/10
1500/1500 [==============================] - 55s 36ms/step - loss: 0.2262 - accuracy: 0.9
166 - val_loss: 0.2979 - val_accuracy: 0.8946
Epoch 8/10
1500/1500 [==============================] - 57s 38ms/step - loss: 0.2083 - accuracy: 0.9
221 - val_loss: 0.2760 - val_accuracy: 0.9053
Epoch 9/10
1500/1500 [==============================] - 55s 36ms/step - loss: 0.1955 - accuracy: 0.9
281 - val_loss: 0.2734 - val_accuracy: 0.9035
Epoch 10/10
1500/1500 [==============================] - 56s 38ms/step - loss: 0.1834 - accuracy: 0.9
320 - val_loss: 0.3079 - val_accuracy: 0.9000
```

In [ ]:

```
# Create a heatmap for each pooling size
for pool_size in pool_sizes:
    heatmap_data = np.zeros((len(filter_sizes), len(filter_sizes)))
    for filters1, kernel_size1, filters2, kernel_size2, p_size, accuracy in maxpool_resu
lts:
        if p_size == pool_size:
            i = filter_sizes.index(filters1)
            j = filter_sizes.index(filters2)
            heatmap_data[i, j] = accuracy

    plt.figure(figsize=(8, 6))
    sns.heatmap(heatmap_data, annot=True, fmt=".6f", xticklabels=filter_sizes, yticklabe
ls=filter_sizes, cmap="viridis")
    plt.title(f"Validation Accuracy for Pool Size: {pool_size}")
    plt.xlabel("Filters in Layer 2")
    plt.ylabel("Filters in Layer 1")
    plt.show()
```





Discussion

1. **One-layer Feedforward Network (Varying Neurons & Activation Functions) :**
    - **Generally simpler models need to perform more on complex tasks like image classification compared to deeper architectures.**
    - **Activation function (ReLU, Leaky ReLU, etc.) can impact performance, typically with ReLU or its variants performing well.**

- Training time is usually shorter due to simpler architecture.

2. **Two-layer Dense Model:**
   - More capable than a single-layer network due to the added complexity & ability to capture more intricate patterns.
   - Training time increases with the added complexity but is usually manageable.
   - Might start to show signs of overfitting, especially with many neurons.
3. **Two-layer Convolutional Model (Without MaxPooling):**
   - Convolutional layers are better suited for image data, capturing spatial hierarchies.
   - Omitting MaxPooling could lead to a more significant number of parameters & a longer training time.
   - It could lead to overfitting if not regularized properly.
4. **Two-layer Convolutional Model (With MaxPooling):**
   - MaxPooling helps reduce dimensionality, making the network computationally more efficient & less prone to overfitting.
   - Typically, these models balance performance & computational efficiency well.
   - Often the go-to choice for image classification tasks.

Comparing the Approaches:

- **Computational Efficiency:** MaxPooling generally improves computational efficiency by reducing the number of parameters.
- **Overfitting Risk:** Dense models with many neurons & convolutional models without MaxPooling are more susceptible to overfitting.
- **Best Performance:** The convolutional models (especially with MaxPooling) often yield better performance on image datasets due to their ability to capture spatial features.

Architectural Improvements:

- **Adding Dropout Layers:** To prevent overfitting.
- **Batch Normalization:** Can improve training stability & performance.
- **Increasing Depth:** Adding more layers can help, but with diminishing returns & increased risk of overfitting.

Training Time:

- **Shortest Training Time:** Likely the one-layer feedforward network due to its simplicity.
- **Best Trade-off:** A well-designed MaxPooling convolutional model could offer best balance between accuracy & computational demand.

Applied Problem 2

Importing Libraries

Installing `ucimlrepo` library

In [ ]:

```
!pip install ucimlrepo
```

```
Requirement already satisfied: ucimlrepo in /usr/local/lib/python3.10/dist-packages (0.0.
3)
```

Calling Modules

In [ ]:

```
import matplotlib.pyplot as plt
```

```
from sklearn.compose import ColumnTransformer
from sklearn.ensemble import AdaBoostClassifier, BaggingClassifier, GradientBoostingClass
ifier, RandomForestClassifier
from sklearn.impute import SimpleImputer
from sklearn.metrics import accuracy_score
from sklearn.model_selection import GridSearchCV, train_test_split
from sklearn.pipeline import Pipeline
from sklearn.preprocessing import OneHotEncoder, StandardScaler
from sklearn.tree import DecisionTreeClassifier
from ucimlrepo import fetch_ucirepo
```

Data Handling

In [ ]:

```
# fetch dataset
adult = fetch_ucirepo(id=2)

# data (as pandas dataframes)
X = adult.data.features
y = adult.data.targets

# metadata
print(adult.metadata)

# variable information
print(adult.variables)

# Splitting data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=0)

# Identifying numerical and categorical columns
numerical_cols = X_train.select_dtypes(include=['int64', 'float64']).columns
categorical_cols = X_train.select_dtypes(include=['object', 'bool']).columns

# Creating a preprocessing pipeline
numerical_transformer = Pipeline(steps=[
    ('imputer', SimpleImputer(strategy='mean')),
    ('scaler', StandardScaler())])

categorical_transformer = Pipeline(steps=[
    ('imputer', SimpleImputer(strategy='most_frequent')),
    ('onehot', OneHotEncoder(handle_unknown='ignore'))])

preprocessor = ColumnTransformer(
    transformers=[
        ('num', numerical_transformer, numerical_cols),
        ('cat', categorical_transformer, categorical_cols)])

# Preprocessing the data
X_train = preprocessor.fit_transform(X_train)
X_test = preprocessor.transform(X_test)
```


```
{'uci_id': 2, 'name': 'Adult', 'repository_url': 'https://archive.ics.uci.edu/dataset/2/a
dult', 'data_url': 'https://archive.ics.uci.edu/static/public/2/data.csv', 'abstract': 'P
redict whether income exceeds $50K/yr based on census data. Also known as "Census Income"
dataset. ', 'area': 'Social Science', 'tasks': ['Classification'], 'characteristics': ['M
ultivariate'], 'num_instances': 48842, 'num_features': 14, 'feature_types': ['Categorical
', 'Integer'], 'demographics': ['Age', 'Income', 'Education Level', 'Other', 'Race', 'Sex
'], 'target_col': ['income'], 'index_col': None, 'has_missing_values': 'yes', 'missing_va
lues_symbol': 'NaN', 'year_of_dataset_creation': 1996, 'last_updated': 'Mon Aug 07 2023',
'dataset_doi': '10.24432/C5XW20', 'creators': ['Barry Becker', 'Ronny Kohavi'], 'intro_pa
per': None, 'additional_info': {'summary': 'Extraction was done by Barry Becker from the
1994 Census database.  A set of reasonably clean records was extracted using the followin
g conditions: ((AAGE>16) && (AGI>100) && (AFNLWGT>1)&& (HRSWK>0))\r\n\r\nPrediction task
is to determine whether a person makes over 50K a year.\r\n', 'purpose': None, 'funded_by
': None, 'instances_represent': None, 'recommended_data_splits': None, 'sensitive_data':
None, 'preprocessing_description': None, 'variable_info': 'Listing of attributes:\r\n\r\n
>50K, <=50K.\r\n\r\nage: continuous.\r\nworkclass: Private, Self-emp-not-inc, Self-emp-in
```

c, Federal-gov, Local-gov, State-gov, Without-pay, Never-worked.\r\nfnlwgt: continuous.\r
\neducation: Bachelors, Some-college, 11th, HS-grad, Prof-school, Assoc-acdm, Assoc-voc,
9th, 7th-8th, 12th, Masters, 1st-4th, 10th, Doctorate, 5th-6th, Preschool.\r\neducation-n
um: continuous.\r\nmarital-status: Married-civ-spouse, Divorced, Never-married, Separated
, Widowed, Married-spouse-absent, Married-AF-spouse.\r\noccupation: Tech-support, Craft-r
epair, Other-service, Sales, Exec-managerial, Prof-specialty, Handlers-cleaners, Machine-
op-inspct, Adm-clerical, Farming-fishing, Transport-moving, Priv-house-serv, Protective-s
erv, Armed-Forces.\r\nrelationship: Wife, Own-child, Husband, Not-in-family, Other-relati
ve, Unmarried.\r\nrace: White, Asian-Pac-Islander, Amer-Indian-Eskimo, Other, Black.\r\ns
ex: Female, Male.\r\ncapital-gain: continuous.\r\ncapital-loss: continuous.\r\nhours-per-
week: continuous.\r\nnative-country: United-States, Cambodia, England, Puerto-Rico, Canad
a, Germany, Outlying-US(Guam-USVI-etc), India, Japan, Greece, South, China, Cuba, Iran, H
onduras, Philippines, Italy, Poland, Jamaica, Vietnam, Mexico, Portugal, Ireland, France,
Dominican-Republic, Laos, Ecuador, Taiwan, Haiti, Columbia, Hungary, Guatemala, Nicaragua
, Scotland, Thailand, Yugoslavia, El-Salvador, Trinadad&Tobago, Peru, Hong, Holand-Nether
lands.', 'citation': None}}

	name	role	type	demographic
0	age	Feature	Integer	Age
1	workclass	Feature	Categorical	Income
2	fnlwgt	Feature	Integer	None
3	education	Feature	Categorical	Education Level
4	education-num	Feature	Integer	Education Level
5	marital-status	Feature	Categorical	Other
6	occupation	Feature	Categorical	Other
7	relationship	Feature	Categorical	Other
8	race	Feature	Categorical	Race
9	sex	Feature	Binary	Sex
10	capital-gain	Feature	Integer	None
11	capital-loss	Feature	Integer	None
12	hours-per-week	Feature	Integer	None
13	native-country	Feature	Categorical	Other
14	income	Target	Binary	Income

	description	units	missing_values
0	N/A	None	no
1	Private, Self-emp-not-inc, Self-emp-inc, Feder...	None	yes
2	None	None	no
3	Bachelors, Some-college, 11th, HS-grad, Prof-...	None	no
4	None	None	no
5	Married-civ-spouse, Divorced, Never-married, S...	None	no
6	Tech-support, Craft-repair, Other-service, Sal...	None	yes
7	Wife, Own-child, Husband, Not-in-family, Other...	None	no
8	White, Asian-Pac-Islander, Amer-Indian-Eskimo,...	None	no
9	Female, Male.	None	no
10	None	None	no
11	None	None	no
12	None	None	no
13	United-States, Cambodia, England, Puerto-Rico,...	None	yes
14	>50K, <=50K.	None	no

Loss Functions

In [ ]:

```
# Decision Tree with Gini index
dt_gini = DecisionTreeClassifier(criterion='gini', random_state=0)
dt_gini.fit(X_train, y_train)

# Decision Tree with Entropy
dt_entropy = DecisionTreeClassifier(criterion='entropy', random_state=0)
dt_entropy.fit(X_train, y_train)

# Random Forest with Gini index
rf_gini = RandomForestClassifier(criterion='gini', random_state=0)
rf_gini.fit(X_train, y_train)

# Random Forest with Entropy
rf_entropy = RandomForestClassifier(criterion='entropy', random_state=0)
rf_entropy.fit(X_train, y_train)
```

```
# Bagging with Decision Tree (Gini index)
bagging_gini = BaggingClassifier(base_estimator=DecisionTreeClassifier(criterion='gini')
, random_state=0)
bagging_gini.fit(X_train, y_train)

# Bagging with Decision Tree (Entropy)
bagging_entropy = BaggingClassifier(base_estimator=DecisionTreeClassifier(criterion='entr
opy'), random_state=0)
bagging_entropy.fit(X_train, y_train)
```

```
<ipython-input-4-5d1d42ca6d77>:11: DataConversionWarning: A column-vector y was passed wh
en a 1d array was expected. Please change the shape of y to (n_samples,), for example usi
ng ravel().
  rf_gini.fit(X_train, y_train)
<ipython-input-4-5d1d42ca6d77>:15: DataConversionWarning: A column-vector y was passed wh
en a 1d array was expected. Please change the shape of y to (n_samples,), for example usi
ng ravel().
  rf_entropy.fit(X_train, y_train)
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_bagging.py:802: DataConversionW
arning: A column-vector y was passed when a 1d array was expected. Please change the shap
e of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_base.py:166: FutureWarning: `ba
se_estimator` was renamed to `estimator` in version 1.2 and will be removed in 1.4.
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_bagging.py:802: DataConversionW
arning: A column-vector y was passed when a 1d array was expected. Please change the shap
e of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
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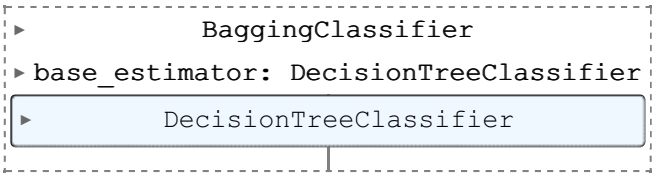
  warnings.warn(
```

Out[ ]:



In [ ]:

```
models = [dt_gini, dt_entropy, rf_gini, rf_entropy, bagging_gini, bagging_entropy]
model_names = ['DT Gini', 'DT Entropy', 'RF Gini', 'RF Entropy', 'Bagging Gini', 'Bagging
Entropy']

# Evaluating accuracy
for model, name in zip(models, model_names):
    y_pred = model.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)
    print(f'Accuracy of {name}: {accuracy:.2f}')
```

```
Accuracy of DT Gini: 0.47
Accuracy of DT Entropy: 0.47
Accuracy of RF Gini: 0.54
Accuracy of RF Entropy: 0.54
Accuracy of Bagging Gini: 0.52
Accuracy of Bagging Entropy: 0.53
```

In [ ]:

```
# Function to calculate OOB error
def get_oob_error(model, X_train, y_train, n_estimators):
    oob_errors = []
    for n in n_estimators:
        model.set_params(n_estimators=n, oob_score=True)
        model.fit(X_train, y_train)
        oob_error = 1 - model.oob_score_
        oob_errors.append(oob_error)
    return oob_errors
```

In [ ]:

```
n_estimators_range = range(10, 210, 10)

rf_oob_errors = get_oob_error(RandomForestClassifier(oob_score=True, random_state=0), X_t
rain, y_train, n_estimators_range)

bagging_oob_errors = get_oob_error(BaggingClassifier(base_estimator=DecisionTreeClassifie
r(), oob_score=True, random_state=0), X_train, y_train, n_estimators_range)

plt.figure(figsize=(10, 6))

plt.plot(n_estimators_range, rf_oob_errors, label='Random Forest OOB Error', color='blue'
)
plt.plot(n_estimators_range, bagging_oob_errors, label='Bagging OOB Error', color='green'
)

plt.legend()
plt.xlabel('Number of Trees')
plt.ylabel('OOB Error')
plt.title('OOB Error vs Number of Trees')

plt.show()
```

```
<ipython-input-6-4c05ab75ad5c>:6: DataConversionWarning: A column-vector y was passed whe
n a 1d array was expected. Please change the shape of y to (n_samples,), for example usin
g ravel().
  model.fit(X_train, y_train)
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_forest.py:583: UserWarning: Som
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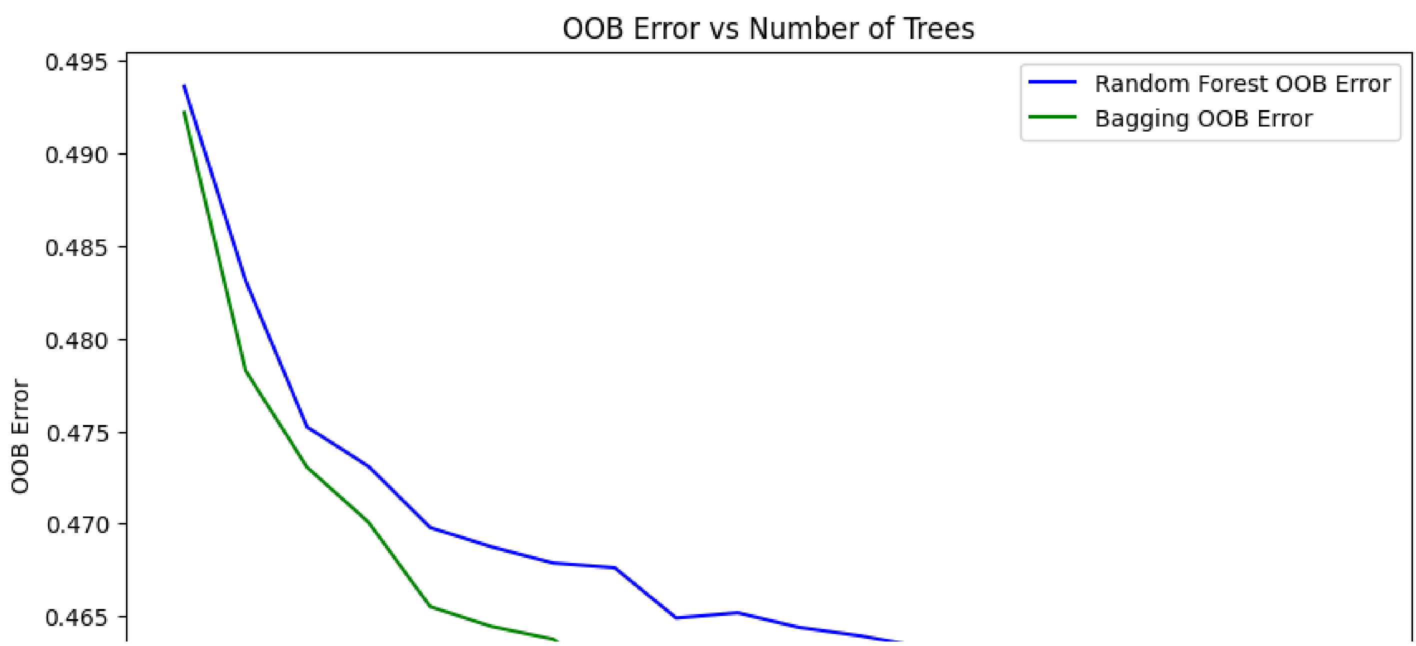
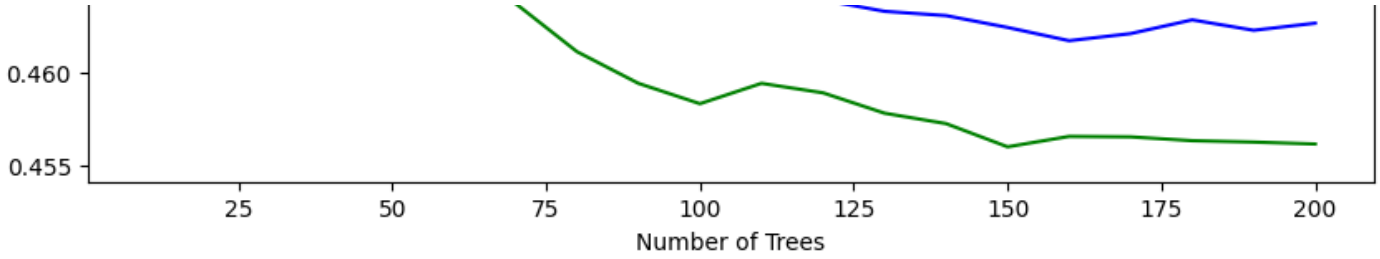
```





Overfitting Attempts (Hyperparameter Damaging)

Decision Tree Implementation

In [ ]:

```
# Train an overfitted decision tree
dt_overfit = DecisionTreeClassifier(max_depth=None)  # No limit on depth
dt_overfit.fit(X_train, y_train)

# Evaluate on training and test data
train_accuracy = accuracy_score(y_train, dt_overfit.predict(X_train))
test_accuracy = accuracy_score(y_test, dt_overfit.predict(X_test))

print("Decision Tree - Train Accuracy:", train_accuracy)
print("Decision Tree - Test Accuracy:", test_accuracy)
```

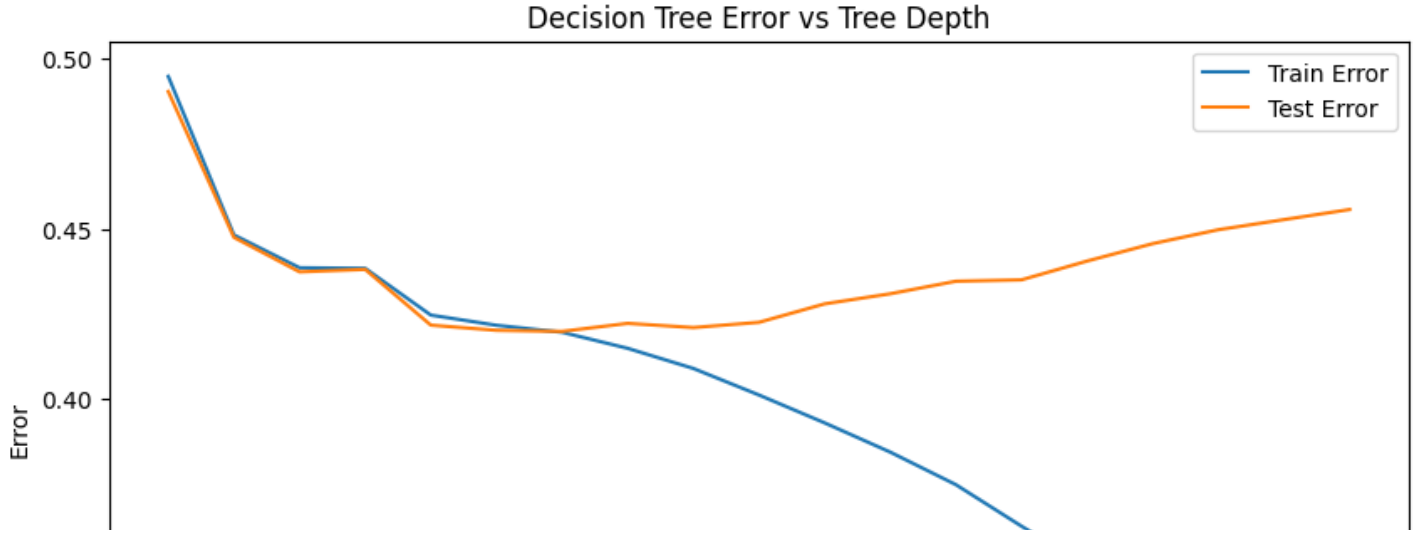
```
Decision Tree - Train Accuracy: 0.9996161031914621
Decision Tree - Test Accuracy: 0.46790869075647457
```

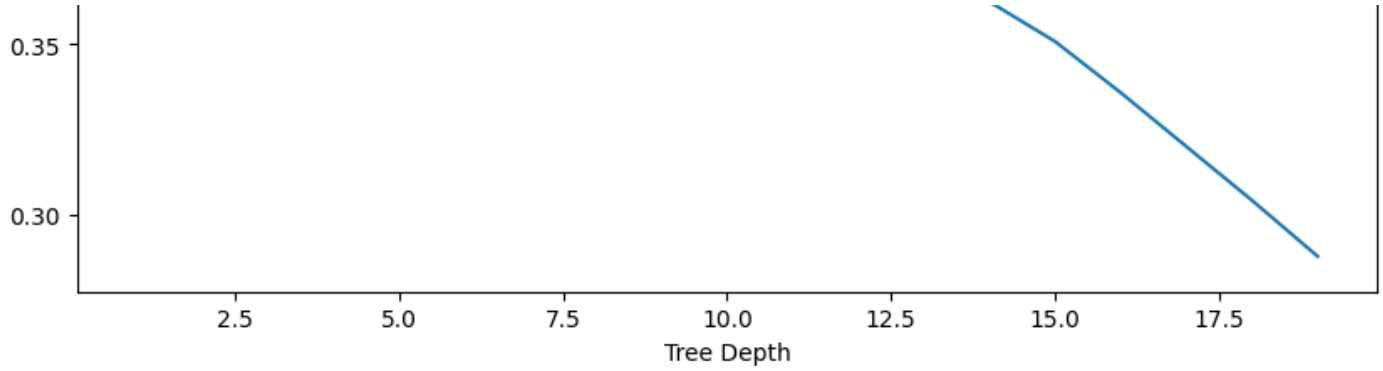
In [ ]:

```
max_depths = range(1, 20)
train_errors = []
test_errors = []

for depth in max_depths:
    model = DecisionTreeClassifier(max_depth=depth)
    model.fit(X_train, y_train)
    train_errors.append(1 - accuracy_score(y_train, model.predict(X_train)))
    test_errors.append(1 - accuracy_score(y_test, model.predict(X_test)))

# Plotting
plt.figure(figsize=(10, 6))
plt.plot(max_depths, train_errors, label='Train Error')
plt.plot(max_depths, test_errors, label='Test Error')
plt.xlabel('Tree Depth')
plt.ylabel('Error')
plt.title('Decision Tree Error vs Tree Depth')
plt.legend()
plt.show()
```





Bagging Classifier Implementation

In [ ]:

```
# Using a deep decision tree as the base estimator
bagging_overfit = BaggingClassifier(base_estimator=DecisionTreeClassifier(max_depth=None)
, n_estimators=10)
bagging_overfit.fit(X_train, y_train)

# Evaluating accuracy
train_accuracy = accuracy_score(y_train, bagging_overfit.predict(X_train))
test_accuracy = accuracy_score(y_test, bagging_overfit.predict(X_test))

print("Bagging - Train Accuracy:", train_accuracy)
print("Bagging - Test Accuracy:", test_accuracy)
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_bagging.py:802: DataConversionW
arning: A column-vector y was passed when a 1d array was expected. Please change the shap
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se_estimator` was renamed to `estimator` in version 1.2 and will be removed in 1.4.
  warnings.warn(
```

```
Bagging - Train Accuracy: 0.9738182376577176
Bagging - Test Accuracy: 0.53280786160303
```

In [ ]:

```
n_estimators_range = range(1, 101, 20)
max_depths = range(1, 20)
bagging_train_errors = []
bagging_test_errors = []

for max_depth in max_depths:
# for n_estimators in n_estimators_range:
    bagging_model = BaggingClassifier(base_estimator=DecisionTreeClassifier(max_depth=max
_depth), n_estimators=100)
    bagging_model.fit(X_train, y_train)
    bagging_train_errors.append(1 - accuracy_score(y_train, bagging_model.predict(X_trai
n)))
    bagging_test_errors.append(1 - accuracy_score(y_test, bagging_model.predict(X_test))
)

# Plotting for Bagging
plt.figure(figsize=(10, 6))
# plt.plot(n_estimators_range, bagging_train_errors, label='Bagging Train Error')
# plt.plot(n_estimators_range, bagging_test_errors, label='Bagging Test Error')
plt.plot(max_depths, bagging_train_errors, label='Bagging Train Error')
plt.plot(max_depths, bagging_test_errors, label='Bagging Test Error')
# plt.xlabel('Number of Base Estimators')
plt.xlabel('Tree Depth')
plt.ylabel('Error')
plt.title('Bagging Error vs Tree Depth')
# plt.title('Bagging Error vs Number of Base Estimators')
plt.legend()
plt.show()
```

```
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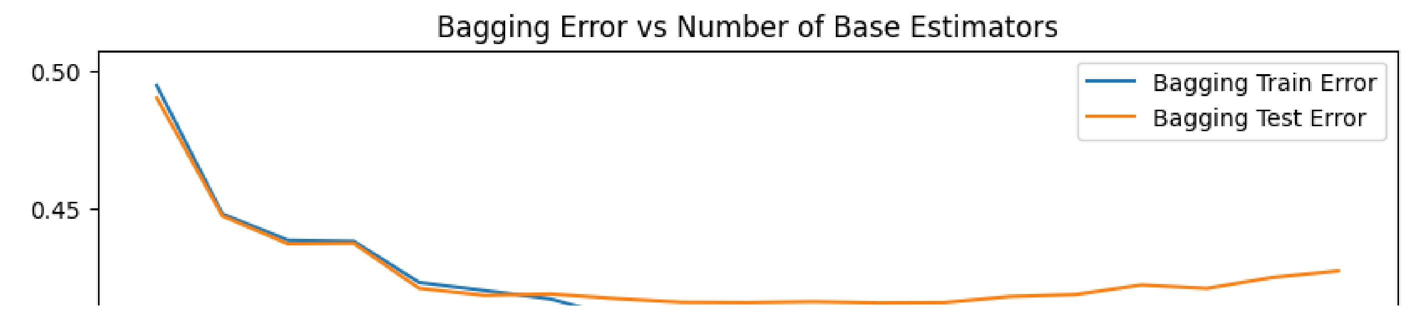

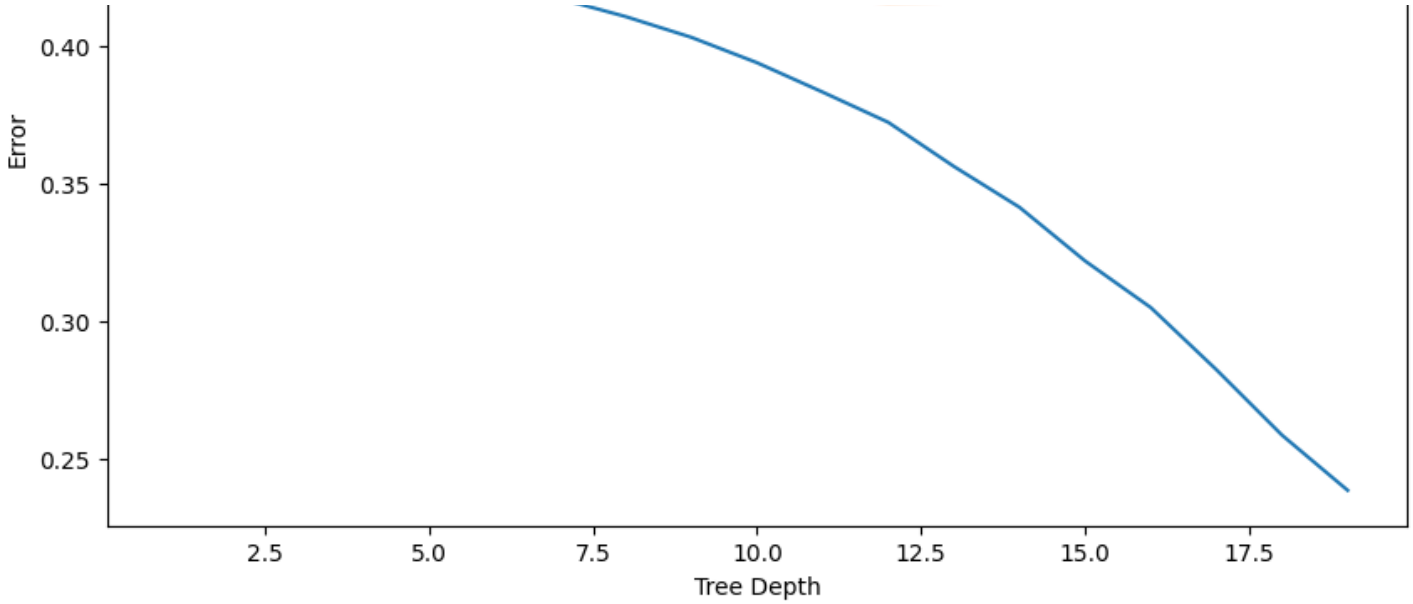

AdaBoost Implementation

In [ ]:

```
# Overfitting AdaBoost
# adaboost_overfit = AdaBoostClassifier(n_estimators=500, learning_rate=1.5)
adaboost_overfit = AdaBoostClassifier(
    base_estimator=DecisionTreeClassifier(max_depth=10),  # Deeper trees
    n_estimators=500,  # More estimators
    learning_rate=1.5  # Higher learning rate
)
adaboost_overfit.fit(X_train, y_train)

# Evaluating accuracy
train_accuracy = accuracy_score(y_train, adaboost_overfit.predict(X_train))
test_accuracy = accuracy_score(y_test, adaboost_overfit.predict(X_test))

print("AdaBoost - Train Accuracy:", train_accuracy)
print("AdaBoost - Test Accuracy:", test_accuracy)
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143: DataConversionW
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  warnings.warn(
```

```
AdaBoost - Train Accuracy: 0.9566964399969288
AdaBoost - Test Accuracy: 0.5442726993551029
```

In [ ]:

```
n_estimators_range = range(1, 401, 20)
max_depths = range(1, 20)
adaboost_train_errors = []
adaboost_test_errors = []

for max_depth in max_depths:
# for n_estimators in n_estimators_range:
    # model = AdaBoostClassifier(n_estimators=n_estimators, random_state=0)
    model = AdaBoostClassifier(
        base_estimator=DecisionTreeClassifier(max_depth=max_depth),
        n_estimators=20,
        learning_rate=1.5
    )
    model.fit(X_train, y_train)
    adaboost_train_errors.append(1 - accuracy_score(y_train, model.predict(X_train)))
    adaboost_test_errors.append(1 - accuracy_score(y_test, model.predict(X_test)))
```

```python
# Plotting
plt.figure(figsize=(10, 6))
# plt.plot(n_estimators_range, adaboost_train_errors, label='Train Error', color='green')
# plt.plot(n_estimators_range, adaboost_test_errors, label='Test Error', color='red')
plt.plot(max_depths, adaboost_train_errors, label='Train Error', color='green')
plt.plot(max_depths, adaboost_test_errors, label='Test Error', color='red')
# plt.xlabel('Number of Estimators')
plt.xlabel('Tree Depth')
plt.ylabel('Error')
# plt.title('AdaBoost Error vs Number of Estimators')
plt.title('AdaBoost Error vs Tree Depth')
plt.legend()
plt.show()
```

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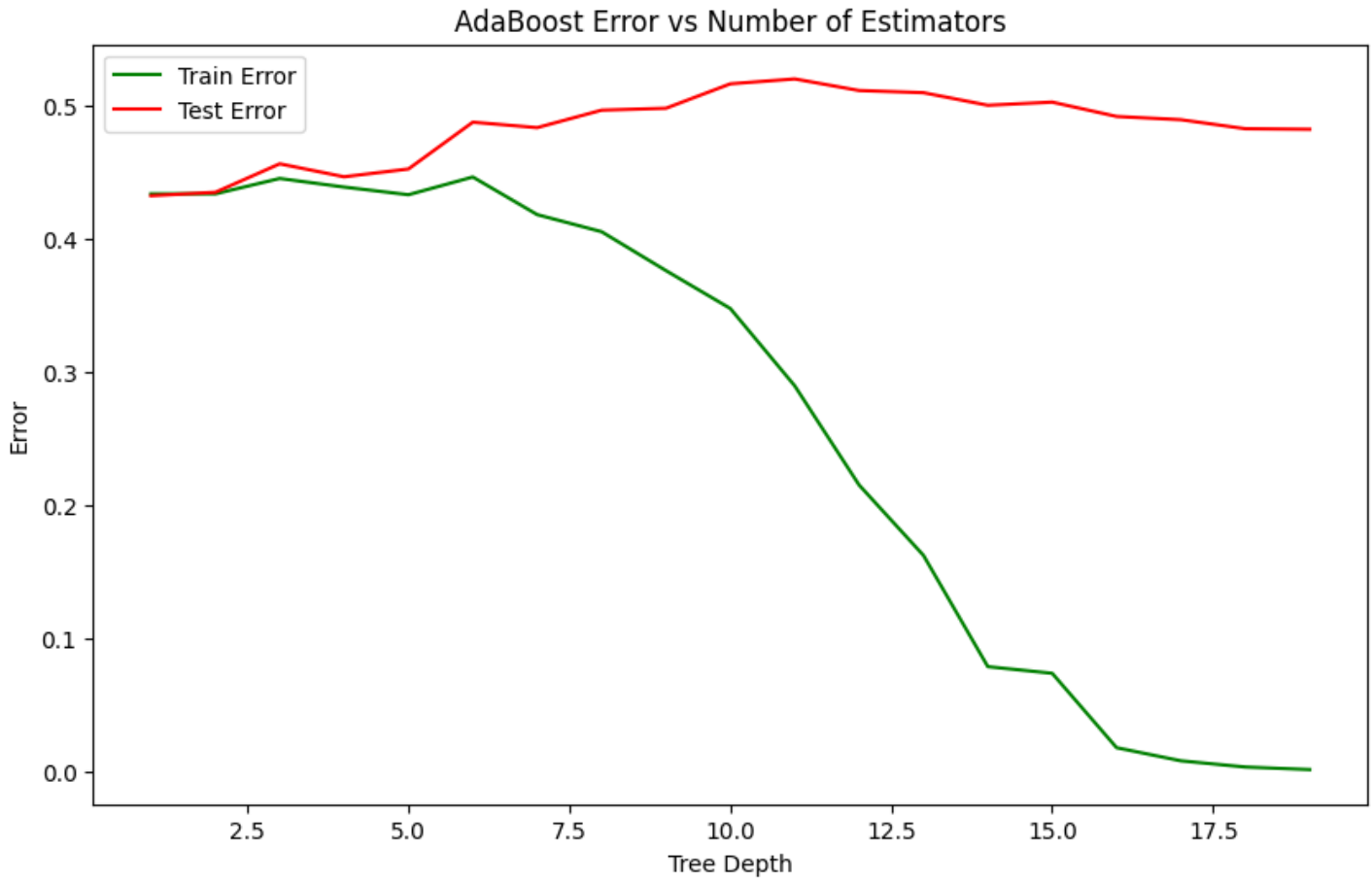

Gradient Boosting Implementation

In [ ]:

```
# Overfitting Gradient Boosting
# gboost_overfit = GradientBoostingClassifier(n_estimators=100, learning_rate=0.5)
gboost_overfit = GradientBoostingClassifier(
    n_estimators=500,  # More estimators
    learning_rate=0.5,  # Higher learning rate
    max_depth=10,  # Deeper trees
    subsample=0.8  # Subsampling
)
gboost_overfit.fit(X_train, y_train)

# Evaluating accuracy
train_accuracy = accuracy_score(y_train, gboost_overfit.predict(X_train))
test_accuracy = accuracy_score(y_test, gboost_overfit.predict(X_test))

print("Gradient Boosting - Train Accuracy:", train_accuracy)
print("Gradient Boosting - Test Accuracy:", test_accuracy)
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_gb.py:437: DataConversionWarning: A column-vector y was passed when a 1d array was expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

```
Gradient Boosting - Train Accuracy: 0.954034755457733
Gradient Boosting - Test Accuracy: 0.5016890162759751
```

In [ ]:

```
n_estimators_range = range(1, 100, 10)
train_errors = []
test_errors = []
```

```python
for n_estimators in n_estimators_range:
    # model = GradientBoostingClassifier(n_estimators=n_estimators)
    model = GradientBoostingClassifier(
        n_estimators=n_estimators,
        learning_rate=0.5,
        max_depth=10,
        subsample=0.8
    )
    model.fit(X_train, y_train)
    train_errors.append(1 - accuracy_score(y_train, model.predict(X_train)))
    test_errors.append(1 - accuracy_score(y_test, model.predict(X_test)))

# Plotting
plt.figure(figsize=(10, 6))
plt.plot(n_estimators_range, train_errors, label='Train Error')
plt.plot(n_estimators_range, test_errors, label='Test Error')
plt.xlabel('Number of Estimators')
plt.ylabel('Error')
plt.title('Gradient Boosting Error vs Number of Estimators')
plt.legend()
plt.show()
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_gb.py:437: DataConversionWarnin
g: A column-vector y was passed when a 1d array was expected. Please change the shape of
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```

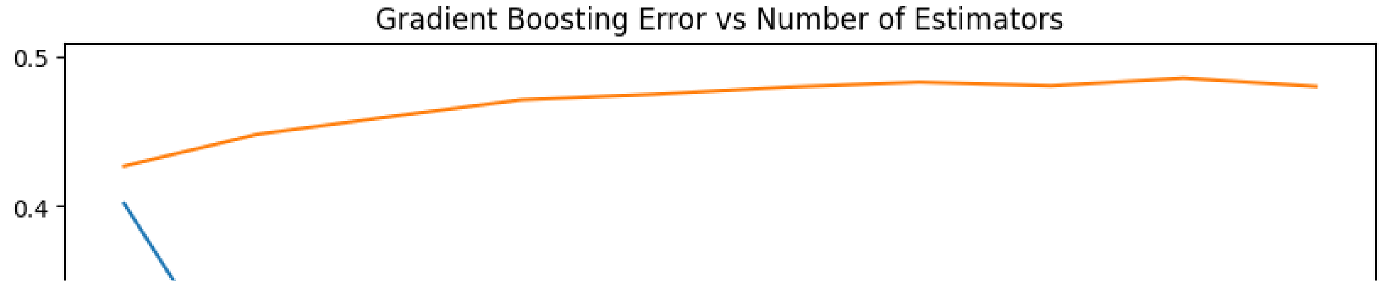

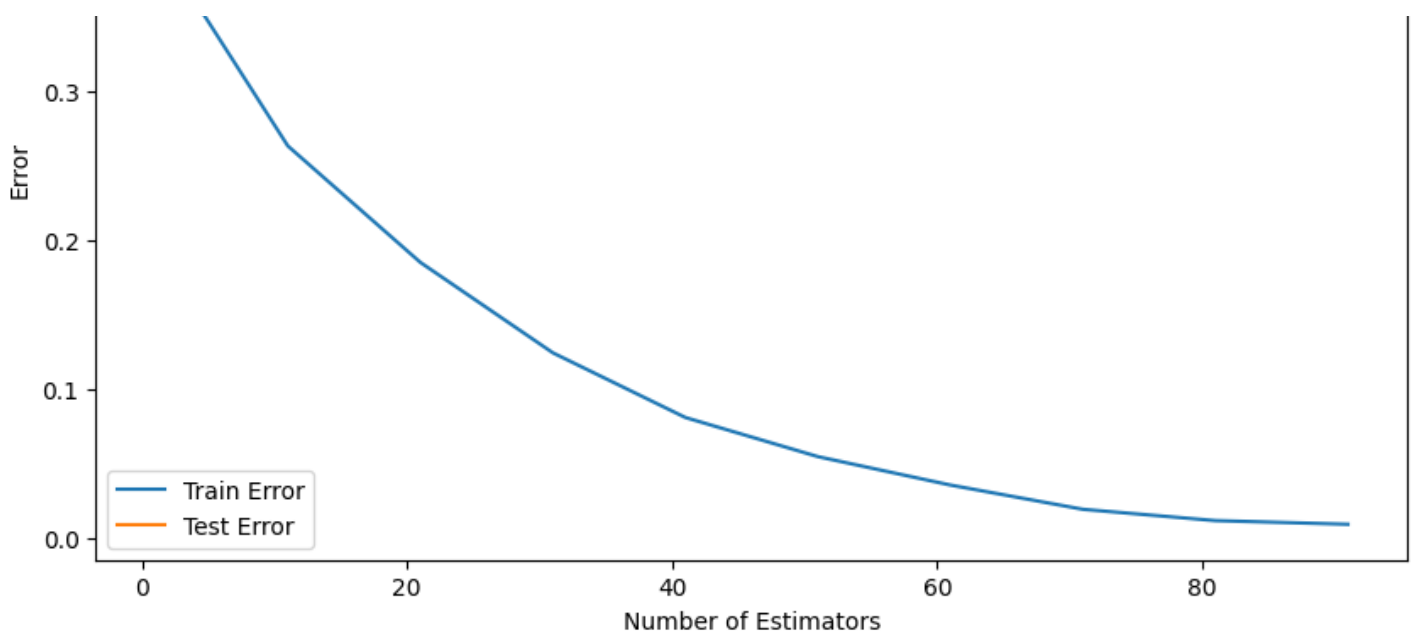

Random Forests Implementation

In [ ]:

```
# Overfitting Random Forests
rf_overfit = RandomForestClassifier(n_estimators=100, max_features='auto', max_depth=Non
e)
rf_overfit.fit(X_train, y_train)

# Evaluating accuracy
train_accuracy = accuracy_score(y_train, rf_overfit.predict(X_train))
test_accuracy = accuracy_score(y_test, rf_overfit.predict(X_test))

print("Random Forests - Train Accuracy:", train_accuracy)
print("Random Forests - Test Accuracy:", test_accuracy)
```

```
<ipython-input-9-abfedad98c2f>:3: DataConversionWarning: A column-vector y was passed whe
n a 1d array was expected. Please change the shape of y to (n_samples,), for example usin
g ravel().
  rf_overfit.fit(X_train, y_train)
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_forest.py:424: FutureWarning: `
max_features='auto'` has been deprecated in 1.1 and will be removed in 1.3. To keep the p
ast behaviour, explicitly set `max_features='sqrt'` or remove this parameter as it is als
o the default value for RandomForestClassifiers and ExtraTreesClassifiers.
  warn(
```

```
Random Forests - Train Accuracy: 0.9996161031914621
Random Forests - Test Accuracy: 0.5354693417954755
```

In [ ]:

```
# Varying the number of trees
n_estimators_range = range(1, 101, 10)
max_depths = range(1, 20)
rf_train_errors = []
rf_test_errors = []

for max_depth in max_depths:
# for n_estimators in n_estimators_range:
    model = RandomForestClassifier(n_estimators=100, max_depth=max_depth, random_state=0
)
    model.fit(X_train, y_train)
    rf_train_errors.append(1 - accuracy_score(y_train, model.predict(X_train)))
    rf_test_errors.append(1 - accuracy_score(y_test, model.predict(X_test)))

# Plotting
plt.figure(figsize=(10, 6))
# plt.plot(n_estimators_range, rf_train_errors, label='Train Error', color='blue')
# plt.plot(n_estimators_range, rf_test_errors, label='Test Error', color='orange')
```

```python
plt.plot(max_depths, rf_train_errors, label='Train Error', color='blue')
plt.plot(max_depths, rf_test_errors, label='Test Error', color='orange')
# plt.xlabel('Number of Trees')
plt.xlabel('Tree Depth')
plt.ylabel('Error')
# plt.title('Random Forest Error vs Number of Trees')
plt.title('Random Forest Error vs Trees Depth')
plt.legend()
plt.show()
```

```
<ipython-input-5-7c7836f45b9d>:10: DataConversionWarning: A column-vector y was passed wh
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```
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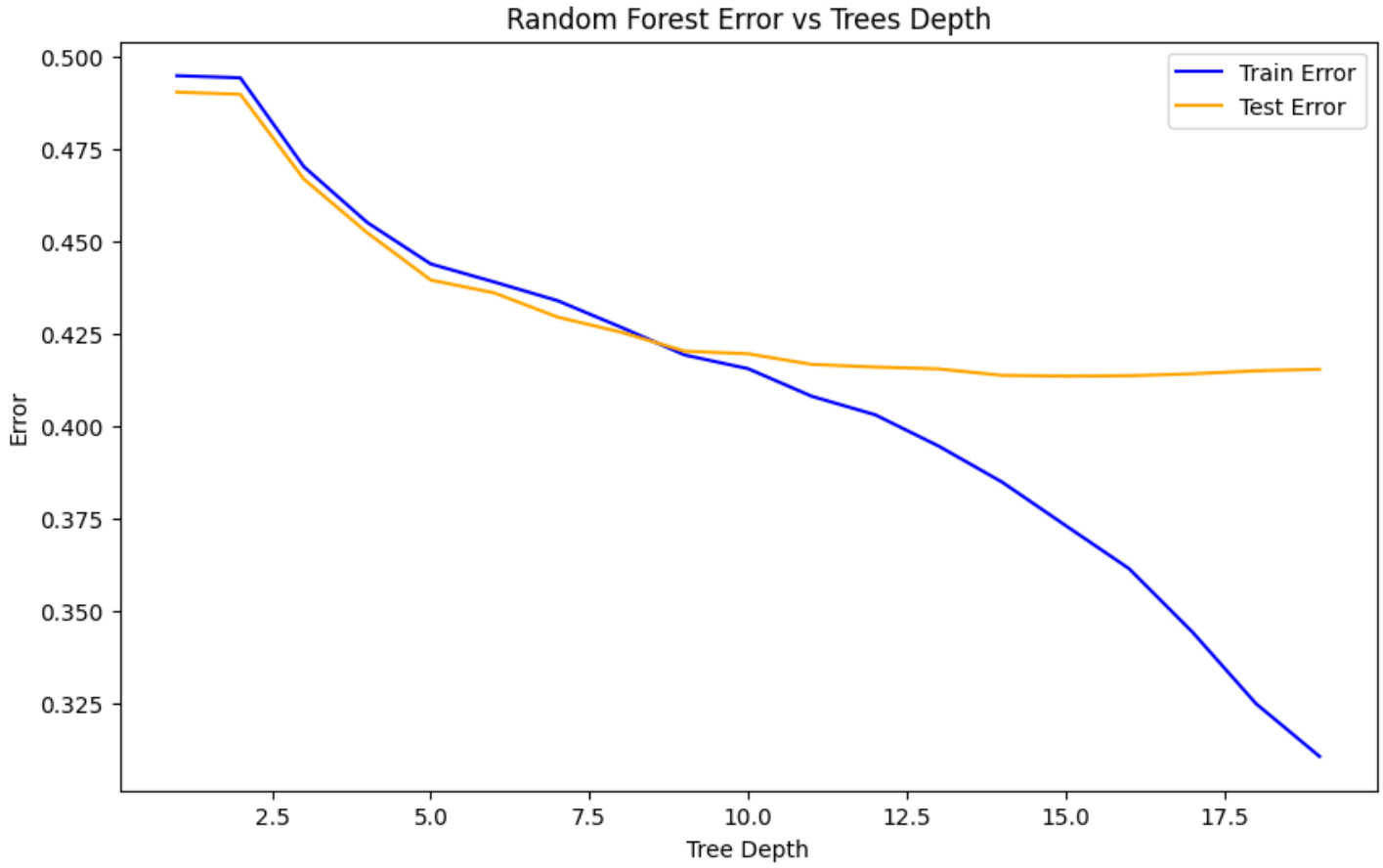
```



Hyperparameter Tuning

Decision Tree Tuning

In [ ]:

```
# Define the parameter grid
param_grid_dt = {
    'max_depth': [3, 5, 10, 20, None],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 4]
}

# Grid search with cross-validation
# dt = DecisionTreeClassifier(random_state=0)
dt_grid_search = GridSearchCV(
    DecisionTreeClassifier(random_state=0),
    param_grid_dt,
    cv=5,
    scoring='accuracy'
)
dt_grid_search.fit(X_train, y_train)
```

```
best_dt = dt_grid_search.best_estimator_
```

In [ ]:

```
best_dt
```

Out[ ]:

```
▾                         DecisionTreeClassifier
DecisionTreeClassifier(max_depth=10, min_samples_leaf=2, min_samples_split=5,
                       random_state=0)
```

Bagging Classification Tuning

In [ ]:

```
param_grid_bagging = {
    'base_estimator__max_depth': [3, 5, 10, 20, None],
    'n_estimators': [10, 50, 100],
    # 'max_samples': [0.5, 1.0],
    # 'max_features': [0.5, 1.0]
}
# bagging = BaggingClassifier(random_state=0)
# bagging = BaggingClassifier(base_estimator=DecisionTreeClassifier())
bagging_grid_search = GridSearchCV(
    BaggingClassifier(base_estimator=DecisionTreeClassifier()),
    param_grid_bagging,
    cv=5,
    scoring='accuracy'
)
bagging_grid_search.fit(X_train, y_train)

best_bagging = bagging_grid_search.best_estimator_
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_bagging.py:802: DataConversionW
arning: A column-vector y was passed when a 1d array was expected. Please change the shap
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In [ ]:

```
best_bagging
```

Out[ ]:

```
▸          BaggingClassifier
```

▸ BaggingClassifier
▸ base_estimator: DecisionTreeClassifier
▸ DecisionTreeClassifier

AdaBoost Tuning

In [ ]:

```
param_grid_ada = {
    'base_estimator__max_depth': [3, 5, 10, 20, None],
    'n_estimators': [50, 100, 200, 400],
    'learning_rate': [0.01, 0.1, 1.0]
}

# adaboost = AdaBoostClassifier(random_state=0)
adaboost_grid_search = GridSearchCV(
    AdaBoostClassifier(base_estimator=DecisionTreeClassifier()),
    param_grid_ada,
    cv=5,
    scoring='accuracy'
)
adaboost_grid_search.fit(X_train, y_train)

best_adaboost = adaboost_grid_search.best_estimator_
```

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```

In [ ]:

```
best_adaboost
```

Gradient Boosting Tuning

In [ ]:

```
param_grid_gb = {
    'base_estimator__max_depth': [3, 5, 10, 20, None],
    'n_estimators': [50, 100, 200, 400],
    'learning_rate': [0.01, 0.1, 1,0]
}

# gb = GradientBoostingClassifier(random_state=0)
gb_grid_search = GridSearchCV(
    GradientBoostingClassifier(),
    param_grid_gb,
    cv=5,
    scoring='accuracy'
)
gb_grid_search.fit(X_train, y_train)

best_gboost = gb_grid_search.best_estimator_
```

In [ ]:

```
best_gboost
```

Random Forests Tuning

In [ ]:

```
param_grid_rf = {
    # 'max_features': ['auto', 'sqrt']
    'max_depth': [3, 5, 10, 20, None],
    'n_estimators': [100, 200, 300],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 4]
}
```

```
# rf = RandomForestClassifier(random_state=0)
rf_grid_search = GridSearchCV(
    RandomForestClassifier(),
    param_grid_rf,
    cv=5,
    scoring='accuracy'
)
rf_grid_search.fit(X_train, y_train)

best_rf = rf_grid_search.best_estimator_
```

In [ ]:

```
best_rf
```

Tuning Results, Discussion, & Interpretations

In [ ]:

```
import pandas as pd

# Assuming you have the best models from GridSearchCV
best_models = {
    'DecisionTree': best_dt,  # best model from DecisionTree GridSearchCV
    'Bagging': best_bagging,  # best model from BaggingClassifier GridSearchCV
    'RandomForest': best_rf,  # best model from RandomForest GridSearchCV
    'AdaBoost': best_adaboost,  # best model from AdaBoost GridSearchCV
    'GradientBoosting': best_gboost,  # best model from GradientBoosting GridSearchCV
    # ... Add other models if you have them
}

# Dictionary to store accuracies
accuracies = {
    'Model': [],
    'Train Accuracy': [],
    'Test Accuracy': []
}

# Iterating through each model and calculating accuracies
for model_name, model in best_models.items():
    train_accuracy = accuracy_score(y_train, model.predict(X_train))
    test_accuracy = accuracy_score(y_test, model.predict(X_test))

    accuracies['Model'].append(model_name)
    accuracies['Train Accuracy'].append(train_accuracy)
    accuracies['Test Accuracy'].append(test_accuracy)

# Converting the accuracies to a DataFrame for better visualization
accuracy_df = pd.DataFrame(accuracies)
accuracy_df
```