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In [1]: import os
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.datasets import cifar10
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense
from tensorflow.keras.optimizers import RMSprop
from tensorflow.keras.utils import to_categorical

# Load the CIFAR-10 dataset
(x_train, y_train), (x_test, y_test) = cifar10.load_data()

# Normalize pixel values to range [0, 1]
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0

# Convert Labels to categorical one-hot encoding
num_classes = 10
y_train = to_categorical(y_train, num_classes)
y_test = to_categorical(y_test, num_classes)

# Define the ConvNet model
model = Sequential()
model.add(Conv2D(32, (3, 3), activation='relu', input_shape=(32, 32, 3)))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(Flatten())
model.add(Dense(64, activation='relu'))
model.add(Dense(num_classes, activation='softmax'))

# Compile the model
model.compile(optimizer=RMSprop(lr=0.001), loss='categorical_crossentropy', metrics=['accuracy'])

# Train the model
history = model.fit(x_train, y_train, batch_size=64, epochs=100, validation_split=0.1)

# Evaluate the model on test data
test_loss, test_acc = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', test_loss)
print('Test accuracy:', test_acc)

# Save the model
model.save('dsc650/assignments/assignment06/results/cifar10_model.h5')

# Save the predictions
y_pred = model.predict(x_test)
np.save('dsc650/assignments/assignment06/results/cifar10_predictions.npy', y_pred)

# Plot the training and validation accuracy over epochs
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend(['train', 'val'], loc='upper left')
plt.savefig('dsc650/assignments/assignment06/results/accuracy_plot.png')
```

```
plt.show()

# Plot the training and validation Loss over epochs
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('Model Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend(['train', 'val'], loc='upper right')
plt.savefig('dsc650/assignments/assignment06/results/loss_plot.png')
plt.show()
```

WARNING:absl:`lr` is deprecated, please use `learning_rate` instead, or use the legacy optimizer, e.g.,tf.keras.optimizers.RMSprop.

```
Epoch 1/100
704/704 [=====] - 39s 50ms/step - loss: 1.6456 - accuracy: 0.4055 - val_loss: 1.6812 - val_accuracy: 0.3934
Epoch 2/100
704/704 [=====] - 34s 49ms/step - loss: 1.2239 - accuracy: 0.5705 - val_loss: 1.7612 - val_accuracy: 0.4628
Epoch 3/100
704/704 [=====] - 36s 51ms/step - loss: 1.0333 - accuracy: 0.6391 - val_loss: 1.0892 - val_accuracy: 0.6224
Epoch 4/100
704/704 [=====] - 36s 51ms/step - loss: 0.8986 - accuracy: 0.6873 - val_loss: 1.3267 - val_accuracy: 0.5726
Epoch 5/100
704/704 [=====] - 37s 52ms/step - loss: 0.8016 - accuracy: 0.7238 - val_loss: 1.0009 - val_accuracy: 0.6640
Epoch 6/100
704/704 [=====] - 36s 51ms/step - loss: 0.7125 - accuracy: 0.7543 - val_loss: 1.4823 - val_accuracy: 0.5694
Epoch 7/100
704/704 [=====] - 39s 56ms/step - loss: 0.6341 - accuracy: 0.7786 - val_loss: 1.3042 - val_accuracy: 0.5896
Epoch 8/100
704/704 [=====] - 42s 59ms/step - loss: 0.5641 - accuracy: 0.8044 - val_loss: 1.0829 - val_accuracy: 0.6674
Epoch 9/100
704/704 [=====] - 39s 56ms/step - loss: 0.4956 - accuracy: 0.8271 - val_loss: 0.9666 - val_accuracy: 0.7046
Epoch 10/100
704/704 [=====] - 42s 59ms/step - loss: 0.4330 - accuracy: 0.8471 - val_loss: 0.9717 - val_accuracy: 0.7094
Epoch 11/100
704/704 [=====] - 37s 53ms/step - loss: 0.3770 - accuracy: 0.8675 - val_loss: 1.0793 - val_accuracy: 0.7130
Epoch 12/100
704/704 [=====] - 38s 54ms/step - loss: 0.3252 - accuracy: 0.8867 - val_loss: 1.0726 - val_accuracy: 0.7016
Epoch 13/100
704/704 [=====] - 38s 53ms/step - loss: 0.2796 - accuracy: 0.9014 - val_loss: 1.5241 - val_accuracy: 0.6508
Epoch 14/100
704/704 [=====] - 38s 54ms/step - loss: 0.2384 - accuracy: 0.9161 - val_loss: 1.1786 - val_accuracy: 0.7250
Epoch 15/100
704/704 [=====] - 34s 49ms/step - loss: 0.2019 - accuracy: 0.9300 - val_loss: 1.7966 - val_accuracy: 0.6540
Epoch 16/100
704/704 [=====] - 34s 48ms/step - loss: 0.1754 - accuracy: 0.9396 - val_loss: 1.3932 - val_accuracy: 0.7018
Epoch 17/100
704/704 [=====] - 36s 51ms/step - loss: 0.1536 - accuracy: 0.9468 - val_loss: 1.4938 - val_accuracy: 0.7220
Epoch 18/100
704/704 [=====] - 36s 51ms/step - loss: 0.1390 - accuracy: 0.9518 - val_loss: 1.5186 - val_accuracy: 0.7348
Epoch 19/100
704/704 [=====] - 35s 50ms/step - loss: 0.1290 - accuracy: 0.9559 - val_loss: 1.8979 - val_accuracy: 0.6948
Epoch 20/100
704/704 [=====] - 40s 56ms/step - loss: 0.1143 - accuracy: 0.9599 - val_loss: 1.9838 - val_accuracy: 0.6754
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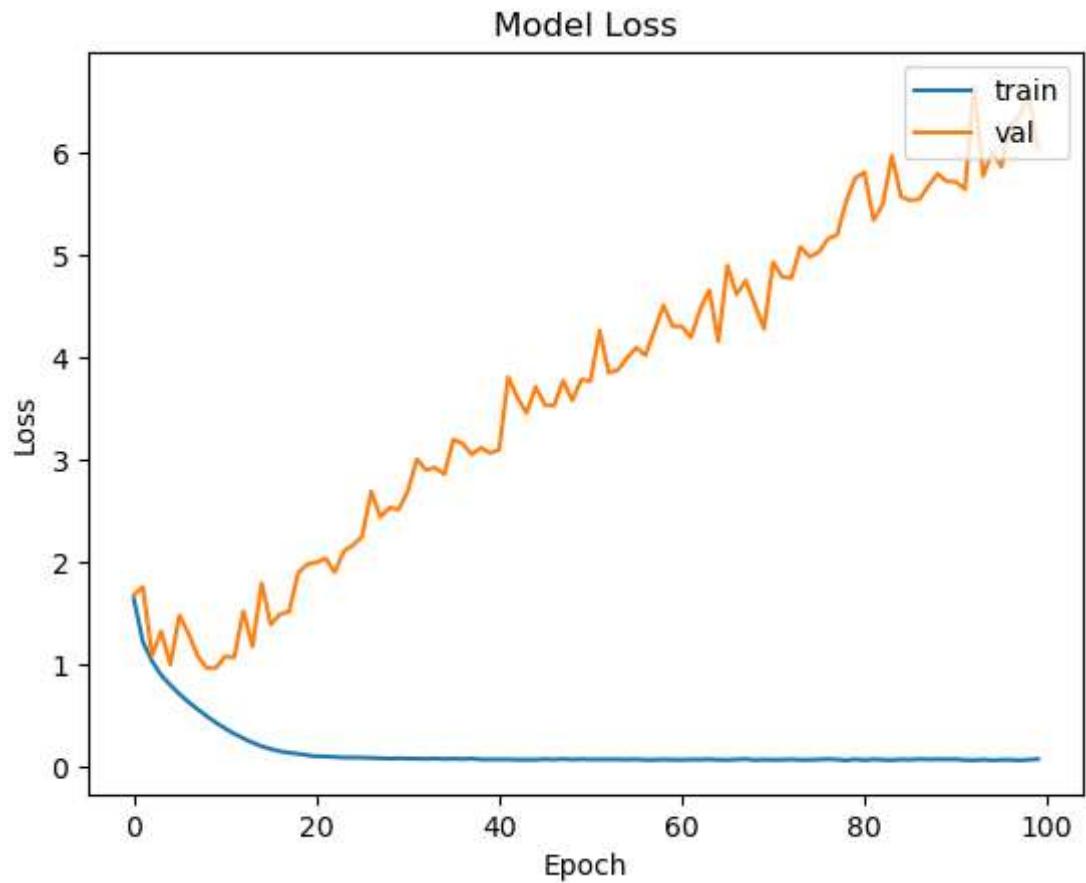
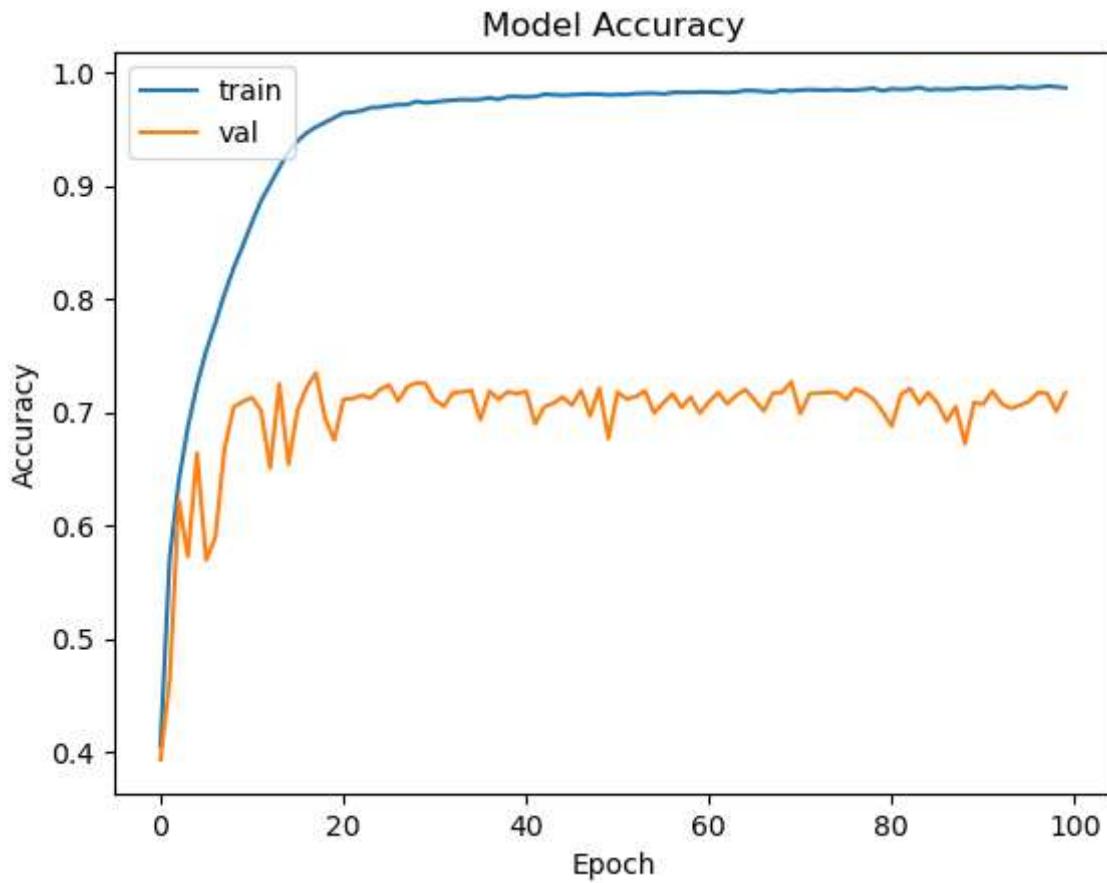
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Epoch 21/100
704/704 [=====] - 38s 53ms/step - loss: 0.1045 - accuracy: 0.9644 - val_loss: 1.9999 - val_accuracy: 0.7112
Epoch 22/100
704/704 [=====] - 38s 54ms/step - loss: 0.1026 - accuracy: 0.9649 - val_loss: 2.0401 - val_accuracy: 0.7120
Epoch 23/100
704/704 [=====] - 35s 50ms/step - loss: 0.0976 - accuracy: 0.9664 - val_loss: 1.9029 - val_accuracy: 0.7150
Epoch 24/100
704/704 [=====] - 36s 51ms/step - loss: 0.0925 - accuracy: 0.9690 - val_loss: 2.1119 - val_accuracy: 0.7124
Epoch 25/100
704/704 [=====] - 35s 50ms/step - loss: 0.0934 - accuracy: 0.9694 - val_loss: 2.1692 - val_accuracy: 0.7200
Epoch 26/100
704/704 [=====] - 36s 51ms/step - loss: 0.0907 - accuracy: 0.9706 - val_loss: 2.2527 - val_accuracy: 0.7242
Epoch 27/100
704/704 [=====] - 35s 49ms/step - loss: 0.0888 - accuracy: 0.9716 - val_loss: 2.6959 - val_accuracy: 0.7100
Epoch 28/100
704/704 [=====] - 35s 49ms/step - loss: 0.0856 - accuracy: 0.9716 - val_loss: 2.4446 - val_accuracy: 0.7226
Epoch 29/100
704/704 [=====] - 35s 50ms/step - loss: 0.0814 - accuracy: 0.9745 - val_loss: 2.5352 - val_accuracy: 0.7258
Epoch 30/100
704/704 [=====] - 35s 49ms/step - loss: 0.0853 - accuracy: 0.9732 - val_loss: 2.5178 - val_accuracy: 0.7254
Epoch 31/100
704/704 [=====] - 35s 49ms/step - loss: 0.0817 - accuracy: 0.9740 - val_loss: 2.6965 - val_accuracy: 0.7108
Epoch 32/100
704/704 [=====] - 44s 63ms/step - loss: 0.0814 - accuracy: 0.9749 - val_loss: 3.0095 - val_accuracy: 0.7054
Epoch 33/100
704/704 [=====] - 43s 61ms/step - loss: 0.0786 - accuracy: 0.9755 - val_loss: 2.9046 - val_accuracy: 0.7170
Epoch 34/100
704/704 [=====] - 37s 53ms/step - loss: 0.0821 - accuracy: 0.9762 - val_loss: 2.9267 - val_accuracy: 0.7180
Epoch 35/100
704/704 [=====] - 35s 50ms/step - loss: 0.0773 - accuracy: 0.9758 - val_loss: 2.8626 - val_accuracy: 0.7192
Epoch 36/100
704/704 [=====] - 36s 51ms/step - loss: 0.0809 - accuracy: 0.9763 - val_loss: 3.2027 - val_accuracy: 0.6934
Epoch 37/100
704/704 [=====] - 36s 51ms/step - loss: 0.0770 - accuracy: 0.9777 - val_loss: 3.1628 - val_accuracy: 0.7186
Epoch 38/100
704/704 [=====] - 36s 52ms/step - loss: 0.0814 - accuracy: 0.9762 - val_loss: 3.0552 - val_accuracy: 0.7114
Epoch 39/100
704/704 [=====] - 36s 51ms/step - loss: 0.0733 - accuracy: 0.9787 - val_loss: 3.1217 - val_accuracy: 0.7182
Epoch 40/100
704/704 [=====] - 36s 51ms/step - loss: 0.0732 - accuracy: 0.9788 - val_loss: 3.0700 - val_accuracy: 0.7162
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Epoch 41/100
704/704 [=====] - 36s 51ms/step - loss: 0.0736 - accuracy: 0.9783 - val_loss: 3.1030 - val_accuracy: 0.7186
Epoch 42/100
704/704 [=====] - 36s 51ms/step - loss: 0.0742 - accuracy: 0.9787 - val_loss: 3.8137 - val_accuracy: 0.6898
Epoch 43/100
704/704 [=====] - 36s 51ms/step - loss: 0.0701 - accuracy: 0.9808 - val_loss: 3.6136 - val_accuracy: 0.7050
Epoch 44/100
704/704 [=====] - 35s 50ms/step - loss: 0.0708 - accuracy: 0.9804 - val_loss: 3.4598 - val_accuracy: 0.7080
Epoch 45/100
704/704 [=====] - 35s 50ms/step - loss: 0.0711 - accuracy: 0.9798 - val_loss: 3.7176 - val_accuracy: 0.7136
Epoch 46/100
704/704 [=====] - 36s 51ms/step - loss: 0.0759 - accuracy: 0.9803 - val_loss: 3.5421 - val_accuracy: 0.7062
Epoch 47/100
704/704 [=====] - 36s 51ms/step - loss: 0.0723 - accuracy: 0.9808 - val_loss: 3.5334 - val_accuracy: 0.7194
Epoch 48/100
704/704 [=====] - 35s 50ms/step - loss: 0.0779 - accuracy: 0.9810 - val_loss: 3.7788 - val_accuracy: 0.6968
Epoch 49/100
704/704 [=====] - 36s 51ms/step - loss: 0.0725 - accuracy: 0.9809 - val_loss: 3.5840 - val_accuracy: 0.7214
Epoch 50/100
704/704 [=====] - 35s 50ms/step - loss: 0.0765 - accuracy: 0.9801 - val_loss: 3.7891 - val_accuracy: 0.6770
Epoch 51/100
704/704 [=====] - 35s 50ms/step - loss: 0.0728 - accuracy: 0.9806 - val_loss: 3.7737 - val_accuracy: 0.7176
Epoch 52/100
704/704 [=====] - 36s 51ms/step - loss: 0.0739 - accuracy: 0.9805 - val_loss: 4.2698 - val_accuracy: 0.7118
Epoch 53/100
704/704 [=====] - 36s 51ms/step - loss: 0.0738 - accuracy: 0.9813 - val_loss: 3.8549 - val_accuracy: 0.7138
Epoch 54/100
704/704 [=====] - 35s 50ms/step - loss: 0.0740 - accuracy: 0.9816 - val_loss: 3.8814 - val_accuracy: 0.7190
Epoch 55/100
704/704 [=====] - 36s 51ms/step - loss: 0.0719 - accuracy: 0.9817 - val_loss: 4.0003 - val_accuracy: 0.6994
Epoch 56/100
704/704 [=====] - 35s 50ms/step - loss: 0.0750 - accuracy: 0.9810 - val_loss: 4.1003 - val_accuracy: 0.7082
Epoch 57/100
704/704 [=====] - 34s 48ms/step - loss: 0.0690 - accuracy: 0.9823 - val_loss: 4.0254 - val_accuracy: 0.7164
Epoch 58/100
704/704 [=====] - 35s 49ms/step - loss: 0.0689 - accuracy: 0.9826 - val_loss: 4.2647 - val_accuracy: 0.7042
Epoch 59/100
704/704 [=====] - 34s 49ms/step - loss: 0.0729 - accuracy: 0.9823 - val_loss: 4.5143 - val_accuracy: 0.7134
Epoch 60/100
704/704 [=====] - 35s 49ms/step - loss: 0.0703 - accuracy: 0.9828 - val_loss: 4.3099 - val_accuracy: 0.6992
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Epoch 61/100
704/704 [=====] - 34s 49ms/step - loss: 0.0694 - accuracy: 0.9828 - val_loss: 4.3091 - val_accuracy: 0.7092
Epoch 62/100
704/704 [=====] - 35s 49ms/step - loss: 0.0725 - accuracy: 0.9825 - val_loss: 4.2011 - val_accuracy: 0.7174
Epoch 63/100
704/704 [=====] - 35s 49ms/step - loss: 0.0716 - accuracy: 0.9822 - val_loss: 4.4744 - val_accuracy: 0.7074
Epoch 64/100
704/704 [=====] - 35s 49ms/step - loss: 0.0748 - accuracy: 0.9828 - val_loss: 4.6644 - val_accuracy: 0.7150
Epoch 65/100
704/704 [=====] - 35s 49ms/step - loss: 0.0697 - accuracy: 0.9841 - val_loss: 4.1623 - val_accuracy: 0.7200
Epoch 66/100
704/704 [=====] - 35s 50ms/step - loss: 0.0686 - accuracy: 0.9840 - val_loss: 4.9041 - val_accuracy: 0.7108
Epoch 67/100
704/704 [=====] - 35s 50ms/step - loss: 0.0733 - accuracy: 0.9832 - val_loss: 4.6217 - val_accuracy: 0.7012
Epoch 68/100
704/704 [=====] - 35s 49ms/step - loss: 0.0767 - accuracy: 0.9827 - val_loss: 4.7563 - val_accuracy: 0.7168
Epoch 69/100
704/704 [=====] - 35s 50ms/step - loss: 0.0677 - accuracy: 0.9846 - val_loss: 4.5188 - val_accuracy: 0.7176
Epoch 70/100
704/704 [=====] - 35s 50ms/step - loss: 0.0711 - accuracy: 0.9836 - val_loss: 4.2862 - val_accuracy: 0.7270
Epoch 71/100
704/704 [=====] - 35s 50ms/step - loss: 0.0693 - accuracy: 0.9845 - val_loss: 4.9367 - val_accuracy: 0.6988
Epoch 72/100
704/704 [=====] - 35s 50ms/step - loss: 0.0703 - accuracy: 0.9848 - val_loss: 4.7924 - val_accuracy: 0.7162
Epoch 73/100
704/704 [=====] - 35s 50ms/step - loss: 0.0735 - accuracy: 0.9846 - val_loss: 4.7803 - val_accuracy: 0.7170
Epoch 74/100
704/704 [=====] - 35s 49ms/step - loss: 0.0687 - accuracy: 0.9843 - val_loss: 5.0844 - val_accuracy: 0.7174
Epoch 75/100
704/704 [=====] - 35s 50ms/step - loss: 0.0698 - accuracy: 0.9850 - val_loss: 4.9888 - val_accuracy: 0.7176
Epoch 76/100
704/704 [=====] - 35s 50ms/step - loss: 0.0723 - accuracy: 0.9843 - val_loss: 5.0342 - val_accuracy: 0.7112
Epoch 77/100
704/704 [=====] - 35s 50ms/step - loss: 0.0771 - accuracy: 0.9845 - val_loss: 5.1643 - val_accuracy: 0.7206
Epoch 78/100
704/704 [=====] - 36s 51ms/step - loss: 0.0726 - accuracy: 0.9852 - val_loss: 5.2044 - val_accuracy: 0.7172
Epoch 79/100
704/704 [=====] - 35s 50ms/step - loss: 0.0644 - accuracy: 0.9861 - val_loss: 5.5314 - val_accuracy: 0.7116
Epoch 80/100
704/704 [=====] - 35s 50ms/step - loss: 0.0754 - accuracy: 0.9838 - val_loss: 5.7599 - val_accuracy: 0.7004
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Epoch 81/100
704/704 [=====] - 35s 50ms/step - loss: 0.0665 - accuracy: 0.9856 - val_loss: 5.8138 - val_accuracy: 0.6878
Epoch 82/100
704/704 [=====] - 35s 50ms/step - loss: 0.0743 - accuracy: 0.9850 - val_loss: 5.3468 - val_accuracy: 0.7158
Epoch 83/100
704/704 [=====] - 35s 50ms/step - loss: 0.0698 - accuracy: 0.9854 - val_loss: 5.5044 - val_accuracy: 0.7212
Epoch 84/100
704/704 [=====] - 35s 50ms/step - loss: 0.0666 - accuracy: 0.9870 - val_loss: 5.9779 - val_accuracy: 0.7076
Epoch 85/100
704/704 [=====] - 35s 50ms/step - loss: 0.0735 - accuracy: 0.9846 - val_loss: 5.5773 - val_accuracy: 0.7174
Epoch 86/100
704/704 [=====] - 35s 50ms/step - loss: 0.0708 - accuracy: 0.9854 - val_loss: 5.5416 - val_accuracy: 0.7082
Epoch 87/100
704/704 [=====] - 36s 51ms/step - loss: 0.0766 - accuracy: 0.9849 - val_loss: 5.5522 - val_accuracy: 0.6920
Epoch 88/100
704/704 [=====] - 35s 50ms/step - loss: 0.0734 - accuracy: 0.9855 - val_loss: 5.6811 - val_accuracy: 0.7050
Epoch 89/100
704/704 [=====] - 35s 50ms/step - loss: 0.0750 - accuracy: 0.9865 - val_loss: 5.8022 - val_accuracy: 0.6724
Epoch 90/100
704/704 [=====] - 35s 50ms/step - loss: 0.0745 - accuracy: 0.9857 - val_loss: 5.7275 - val_accuracy: 0.7086
Epoch 91/100
704/704 [=====] - 35s 50ms/step - loss: 0.0753 - accuracy: 0.9860 - val_loss: 5.7220 - val_accuracy: 0.7072
Epoch 92/100
704/704 [=====] - 36s 51ms/step - loss: 0.0675 - accuracy: 0.9868 - val_loss: 5.6493 - val_accuracy: 0.7186
Epoch 93/100
704/704 [=====] - 35s 50ms/step - loss: 0.0661 - accuracy: 0.9871 - val_loss: 6.6578 - val_accuracy: 0.7078
Epoch 94/100
704/704 [=====] - 35s 50ms/step - loss: 0.0718 - accuracy: 0.9860 - val_loss: 5.7786 - val_accuracy: 0.7034
Epoch 95/100
704/704 [=====] - 35s 50ms/step - loss: 0.0653 - accuracy: 0.9875 - val_loss: 6.0231 - val_accuracy: 0.7062
Epoch 96/100
704/704 [=====] - 35s 50ms/step - loss: 0.0697 - accuracy: 0.9866 - val_loss: 5.8710 - val_accuracy: 0.7094
Epoch 97/100
704/704 [=====] - 35s 50ms/step - loss: 0.0693 - accuracy: 0.9867 - val_loss: 6.2735 - val_accuracy: 0.7174
Epoch 98/100
704/704 [=====] - 36s 51ms/step - loss: 0.0647 - accuracy: 0.9880 - val_loss: 6.3727 - val_accuracy: 0.7166
Epoch 99/100
704/704 [=====] - 36s 51ms/step - loss: 0.0705 - accuracy: 0.9873 - val_loss: 6.5630 - val_accuracy: 0.7008
Epoch 100/100
704/704 [=====] - 36s 51ms/step - loss: 0.0771 - accuracy: 0.9865 - val_loss: 6.0418 - val_accuracy: 0.7174
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Test loss: 6.722339630126953
Test accuracy: 0.7020000219345093
313/313 [=====] - 6s 7ms/step



In []: