Class Challenge: Image Classification of COVID-19 X-rays

Task 2 [Total points: 30]

Setup

- This assignment involves the following packages: 'matplotlib', 'numpy', and 'sklearn'.
- If you are using conda, use the following commands to install the above packages:

```
conda install matplotlib
conda install numpy
conda install -c anaconda scikit-learn
```

- If you are using pip, use use the following commands to install the above packages:

```
pip install matplotlib
pip install numpy
pip install sklearn
```

Data

Please download the data using the following link: COVID-19.

- After downloading 'Covid_Data_GradientCrescent.zip', unzip the file and you should see the following data structure:

|--all
|--------train
|--------test
|--two
|--------train
|--------test

- Put the 'all' folder, the 'two' folder and this python notebook in the **same directory** so that the following code can correctly locate the data.

[20 points] Multi-class Classification

In [2]:
```
import os

import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.preprocessing.image import ImageDataGenerator
```

```
os.environ['OMP_NUM_THREADS'] = '1'
os.environ['CUDA_VISIBLE_DEVICES'] = '-1'
tf.__version__
```

Out[2]: '2.6.0'

Load Image Data

In [20]:
```
DATA_LIST = os.listdir('all/train')
DATASET_PATH  = 'all/train'
TEST_DIR =  'all/test'
IMAGE_SIZE    = (224, 224)
NUM_CLASSES   = len(DATA_LIST)
BATCH_SIZE    = 10  # try reducing batch size or freeze more layers if your GPU runs ou
NUM_EPOCHS    = 100
LEARNING_RATE = 0.0005 # start off with high rate first 0.001 and experiment with reduc
```

Generate Training and Validation Batches

In [4]:
```
train_datagen = ImageDataGenerator(rescale=1./255,rotation_range=50,featurewise_center
                                   featurewise_std_normalization = True,width_shift_ran
                                   height_shift_range=0.2,shear_range=0.25,zoom_range=0
                                   zca_whitening = True,channel_shift_range = 20,
                                   horizontal_flip = True,vertical_flip = True,
                                   validation_split = 0.2,fill_mode='constant')


train_batches = train_datagen.flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                  shuffle=True,batch_size=BATCH_SIZE,
                                                  subset = "training",seed=42,
                                                  class_mode="categorical")

valid_batches = train_datagen.flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                  shuffle=True,batch_size=BATCH_SIZE,
                                                  subset = "validation",
                                                  seed=42,class_mode="categorical")
```

```
Found 216 images belonging to 4 classes.
Found 54 images belonging to 4 classes.
C:\ProgramData\Anaconda3\lib\site-packages\keras_preprocessing\image\image_data_generato
r.py:342: UserWarning: This ImageDataGenerator specifies `zca_whitening` which overrides
setting of`featurewise_std_normalization`.
  warnings.warn('This ImageDataGenerator specifies '
```

Model 1: VGG16

[10 points] Build Model

Hint: Starting from a pre-trained model typically helps performance on a new task, e.g. starting with weights obtained by training on ImageNet.

In [5]:
```
vgg16 = tf.keras.applications.VGG16(weights='imagenet', include_top=False, input_shape=
vgg16.trainable = False
```

```
model = tf.keras.Sequential([
    vgg16,
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(128, activation='relu'),
    tf.keras.layers.Dense(4, activation='softmax')
])
model.compile(optimizer = 'adam', loss = 'categorical_crossentropy', metrics = ['catego
```

In [6]:

```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
vgg16 (Functional)           (None, 7, 7, 512)         14714688
_________________________________________________________________
flatten (Flatten)            (None, 25088)             0
_________________________________________________________________
dense (Dense)                (None, 128)               3211392
_________________________________________________________________
dense_1 (Dense)              (None, 4)                 516
=================================================================
Total params: 17,926,596
Trainable params: 3,211,908
Non-trainable params: 14,714,688
_________________________________________________________________
```

[5 points] Train Model

In [8]:

```
#FIT MODEL
print(len(train_batches))
print(len(valid_batches))


STEP_SIZE_TRAIN=train_batches.n//train_batches.batch_size
STEP_SIZE_VALID=valid_batches.n//valid_batches.batch_size



res = model.fit(train_batches, epochs=NUM_EPOCHS, steps_per_epoch=STEP_SIZE_TRAIN, \
          validation_data=valid_batches, validation_steps=STEP_SIZE_VALID)
```

```
22
6
C:\ProgramData\Anaconda3\lib\site-packages\keras_preprocessing\image\image_data_generato
r.py:720: UserWarning: This ImageDataGenerator specifies `featurewise_center`, but it ha
sn't been fit on any training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '
C:\ProgramData\Anaconda3\lib\site-packages\keras_preprocessing\image\image_data_generato
r.py:739: UserWarning: This ImageDataGenerator specifies `zca_whitening`, but it hasn't
been fit on any training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '
Epoch 1/100
21/21 [==============================] - 15s 679ms/step - loss: 2.2291 - categorical_acc
uracy: 0.3641 - val_loss: 1.0474 - val_categorical_accuracy: 0.5200
Epoch 2/100
21/21 [==============================] - 13s 627ms/step - loss: 1.2767 - categorical_acc
```

```
uracy: 0.5049 - val_loss: 0.9806 - val_categorical_accuracy: 0.6400
Epoch 3/100
21/21 [==============================] - 13s 630ms/step - loss: 1.2193 - categorical_acc
uracy: 0.5388 - val_loss: 1.4163 - val_categorical_accuracy: 0.5600
Epoch 4/100
21/21 [==============================] - 13s 627ms/step - loss: 1.2170 - categorical_acc
uracy: 0.5485 - val_loss: 1.2122 - val_categorical_accuracy: 0.5800
Epoch 5/100
21/21 [==============================] - 13s 633ms/step - loss: 1.0722 - categorical_acc
uracy: 0.5922 - val_loss: 1.0407 - val_categorical_accuracy: 0.4800
Epoch 6/100
21/21 [==============================] - 13s 630ms/step - loss: 1.0387 - categorical_acc
uracy: 0.5922 - val_loss: 0.9112 - val_categorical_accuracy: 0.6400
Epoch 7/100
21/21 [==============================] - 13s 630ms/step - loss: 0.8511 - categorical_acc
uracy: 0.6796 - val_loss: 0.8962 - val_categorical_accuracy: 0.7200
Epoch 8/100
21/21 [==============================] - 13s 627ms/step - loss: 0.9210 - categorical_acc
uracy: 0.6019 - val_loss: 0.7324 - val_categorical_accuracy: 0.6600
Epoch 9/100
21/21 [==============================] - 13s 625ms/step - loss: 0.8463 - categorical_acc
uracy: 0.6359 - val_loss: 0.8045 - val_categorical_accuracy: 0.6200
Epoch 10/100
21/21 [==============================] - 13s 625ms/step - loss: 0.8257 - categorical_acc
uracy: 0.6748 - val_loss: 0.8133 - val_categorical_accuracy: 0.7000
Epoch 11/100
21/21 [==============================] - 14s 651ms/step - loss: 0.7880 - categorical_acc
uracy: 0.6602 - val_loss: 0.8591 - val_categorical_accuracy: 0.6000
Epoch 12/100
21/21 [==============================] - 13s 633ms/step - loss: 0.7562 - categorical_acc
uracy: 0.6796 - val_loss: 0.8321 - val_categorical_accuracy: 0.6400
Epoch 13/100
21/21 [==============================] - 13s 630ms/step - loss: 0.7302 - categorical_acc
uracy: 0.7039 - val_loss: 0.8407 - val_categorical_accuracy: 0.6600
Epoch 14/100
21/21 [==============================] - 13s 629ms/step - loss: 0.7030 - categorical_acc
uracy: 0.7233 - val_loss: 1.0960 - val_categorical_accuracy: 0.5200
Epoch 15/100
21/21 [==============================] - 13s 631ms/step - loss: 0.7846 - categorical_acc
uracy: 0.6748 - val_loss: 0.6260 - val_categorical_accuracy: 0.7000
Epoch 16/100
21/21 [==============================] - 13s 639ms/step - loss: 0.9256 - categorical_acc
uracy: 0.6165 - val_loss: 1.0902 - val_categorical_accuracy: 0.5800
Epoch 17/100
21/21 [==============================] - 13s 630ms/step - loss: 0.8917 - categorical_acc
uracy: 0.6117 - val_loss: 1.3743 - val_categorical_accuracy: 0.4600
Epoch 18/100
21/21 [==============================] - 13s 626ms/step - loss: 0.7073 - categorical_acc
uracy: 0.6748 - val_loss: 0.6242 - val_categorical_accuracy: 0.7200
Epoch 19/100
21/21 [==============================] - 13s 631ms/step - loss: 0.8487 - categorical_acc
uracy: 0.6505 - val_loss: 0.7225 - val_categorical_accuracy: 0.7000
Epoch 20/100
21/21 [==============================] - 14s 655ms/step - loss: 0.7119 - categorical_acc
uracy: 0.6990 - val_loss: 0.8855 - val_categorical_accuracy: 0.5000
Epoch 21/100
21/21 [==============================] - 14s 675ms/step - loss: 0.7167 - categorical_acc
uracy: 0.7087 - val_loss: 0.5505 - val_categorical_accuracy: 0.8000
Epoch 22/100
21/21 [==============================] - 14s 674ms/step - loss: 0.6908 - categorical_acc
```

```
uracy: 0.6796 - val_loss: 0.7556 - val_categorical_accuracy: 0.5600
Epoch 23/100
21/21 [==============================] - 14s 687ms/step - loss: 0.6635 - categorical_acc
uracy: 0.6893 - val_loss: 0.7624 - val_categorical_accuracy: 0.6400
Epoch 24/100
21/21 [==============================] - 15s 712ms/step - loss: 0.6713 - categorical_acc
uracy: 0.6845 - val_loss: 0.5872 - val_categorical_accuracy: 0.8200
Epoch 25/100
21/21 [==============================] - 15s 717ms/step - loss: 0.6898 - categorical_acc
uracy: 0.6990 - val_loss: 0.6140 - val_categorical_accuracy: 0.7200
Epoch 26/100
21/21 [==============================] - 15s 704ms/step - loss: 0.6735 - categorical_acc
uracy: 0.6650 - val_loss: 0.7307 - val_categorical_accuracy: 0.6400
Epoch 27/100
21/21 [==============================] - 14s 657ms/step - loss: 0.7651 - categorical_acc
uracy: 0.6505 - val_loss: 0.6007 - val_categorical_accuracy: 0.6800
Epoch 28/100
21/21 [==============================] - 15s 706ms/step - loss: 0.6848 - categorical_acc
uracy: 0.6650 - val_loss: 0.6771 - val_categorical_accuracy: 0.6600
Epoch 29/100
21/21 [==============================] - 15s 704ms/step - loss: 0.6156 - categorical_acc
uracy: 0.7476 - val_loss: 0.5150 - val_categorical_accuracy: 0.7400
Epoch 30/100
21/21 [==============================] - 15s 708ms/step - loss: 0.6662 - categorical_acc
uracy: 0.7282 - val_loss: 0.8201 - val_categorical_accuracy: 0.7000
Epoch 31/100
21/21 [==============================] - 15s 697ms/step - loss: 0.6923 - categorical_acc
uracy: 0.7427 - val_loss: 0.6378 - val_categorical_accuracy: 0.7200
Epoch 32/100
21/21 [==============================] - 15s 708ms/step - loss: 0.5876 - categorical_acc
uracy: 0.7330 - val_loss: 0.5242 - val_categorical_accuracy: 0.7800
Epoch 33/100
21/21 [==============================] - 15s 717ms/step - loss: 0.6702 - categorical_acc
uracy: 0.7573 - val_loss: 0.5628 - val_categorical_accuracy: 0.7400
Epoch 34/100
21/21 [==============================] - 15s 720ms/step - loss: 0.6760 - categorical_acc
uracy: 0.6796 - val_loss: 0.6085 - val_categorical_accuracy: 0.6400
Epoch 35/100
21/21 [==============================] - 16s 745ms/step - loss: 0.5811 - categorical_acc
uracy: 0.7573 - val_loss: 1.3283 - val_categorical_accuracy: 0.6000
Epoch 36/100
21/21 [==============================] - 14s 667ms/step - loss: 0.7387 - categorical_acc
uracy: 0.6602 - val_loss: 0.7400 - val_categorical_accuracy: 0.6400
Epoch 37/100
21/21 [==============================] - 15s 707ms/step - loss: 0.7457 - categorical_acc
uracy: 0.6408 - val_loss: 0.6764 - val_categorical_accuracy: 0.6600
Epoch 38/100
21/21 [==============================] - 15s 703ms/step - loss: 0.6712 - categorical_acc
uracy: 0.6990 - val_loss: 1.0589 - val_categorical_accuracy: 0.5600
Epoch 39/100
21/21 [==============================] - 15s 710ms/step - loss: 0.6915 - categorical_acc
uracy: 0.7087 - val_loss: 0.6743 - val_categorical_accuracy: 0.6200
Epoch 40/100
21/21 [==============================] - 15s 694ms/step - loss: 0.5852 - categorical_acc
uracy: 0.7621 - val_loss: 0.7640 - val_categorical_accuracy: 0.6400
Epoch 41/100
21/21 [==============================] - 14s 672ms/step - loss: 0.6454 - categorical_acc
uracy: 0.7233 - val_loss: 0.9113 - val_categorical_accuracy: 0.6000
Epoch 42/100
21/21 [==============================] - 14s 674ms/step - loss: 0.6946 - categorical_acc
```

```
uracy: 0.7039 - val_loss: 0.7954 - val_categorical_accuracy: 0.6800
Epoch 43/100
21/21 [==============================] - 14s 672ms/step - loss: 0.6023 - categorical_acc
uracy: 0.7476 - val_loss: 0.5490 - val_categorical_accuracy: 0.6800
Epoch 44/100
21/21 [==============================] - 14s 671ms/step - loss: 0.5570 - categorical_acc
uracy: 0.7621 - val_loss: 0.6132 - val_categorical_accuracy: 0.7200
Epoch 45/100
21/21 [==============================] - 14s 684ms/step - loss: 0.5531 - categorical_acc
uracy: 0.7718 - val_loss: 0.7525 - val_categorical_accuracy: 0.6600
Epoch 46/100
21/21 [==============================] - 14s 663ms/step - loss: 0.6058 - categorical_acc
uracy: 0.7573 - val_loss: 0.5611 - val_categorical_accuracy: 0.7000
Epoch 47/100
21/21 [==============================] - 14s 681ms/step - loss: 0.5574 - categorical_acc
uracy: 0.7524 - val_loss: 0.5471 - val_categorical_accuracy: 0.7800
Epoch 48/100
21/21 [==============================] - 14s 673ms/step - loss: 0.5269 - categorical_acc
uracy: 0.7816 - val_loss: 0.6566 - val_categorical_accuracy: 0.6600
Epoch 49/100
21/21 [==============================] - 14s 679ms/step - loss: 0.5212 - categorical_acc
uracy: 0.7767 - val_loss: 0.5557 - val_categorical_accuracy: 0.7400
Epoch 50/100
21/21 [==============================] - 14s 680ms/step - loss: 0.5532 - categorical_acc
uracy: 0.7913 - val_loss: 0.7965 - val_categorical_accuracy: 0.6400
Epoch 51/100
21/21 [==============================] - 14s 679ms/step - loss: 0.6079 - categorical_acc
uracy: 0.7330 - val_loss: 0.8610 - val_categorical_accuracy: 0.6400
Epoch 52/100
21/21 [==============================] - 14s 673ms/step - loss: 0.5460 - categorical_acc
uracy: 0.7718 - val_loss: 0.9379 - val_categorical_accuracy: 0.6200
Epoch 53/100
21/21 [==============================] - 14s 675ms/step - loss: 0.6140 - categorical_acc
uracy: 0.7476 - val_loss: 0.8440 - val_categorical_accuracy: 0.6000
Epoch 54/100
21/21 [==============================] - 14s 676ms/step - loss: 0.5954 - categorical_acc
uracy: 0.7476 - val_loss: 0.6495 - val_categorical_accuracy: 0.7600
Epoch 55/100
21/21 [==============================] - 14s 674ms/step - loss: 0.5348 - categorical_acc
uracy: 0.7864 - val_loss: 0.6188 - val_categorical_accuracy: 0.7000
Epoch 56/100
21/21 [==============================] - 14s 677ms/step - loss: 0.5560 - categorical_acc
uracy: 0.7427 - val_loss: 0.5679 - val_categorical_accuracy: 0.7400
Epoch 57/100
21/21 [==============================] - 14s 673ms/step - loss: 0.5875 - categorical_acc
uracy: 0.7476 - val_loss: 0.6813 - val_categorical_accuracy: 0.6000
Epoch 58/100
21/21 [==============================] - 14s 682ms/step - loss: 0.5748 - categorical_acc
uracy: 0.7476 - val_loss: 0.5886 - val_categorical_accuracy: 0.7200
Epoch 59/100
21/21 [==============================] - 15s 702ms/step - loss: 0.5368 - categorical_acc
uracy: 0.7524 - val_loss: 0.6768 - val_categorical_accuracy: 0.7200
Epoch 60/100
21/21 [==============================] - 15s 697ms/step - loss: 0.5298 - categorical_acc
uracy: 0.8010 - val_loss: 0.6979 - val_categorical_accuracy: 0.7200
Epoch 61/100
21/21 [==============================] - 15s 726ms/step - loss: 0.5597 - categorical_acc
uracy: 0.7233 - val_loss: 0.6975 - val_categorical_accuracy: 0.6000
Epoch 62/100
21/21 [==============================] - 15s 706ms/step - loss: 0.5936 - categorical_acc
```

```
uracy: 0.7233 - val_loss: 0.7930 - val_categorical_accuracy: 0.6600
Epoch 63/100
21/21 [==============================] - 15s 708ms/step - loss: 0.5644 - categorical_acc
uracy: 0.7767 - val_loss: 0.7554 - val_categorical_accuracy: 0.5800
Epoch 64/100
21/21 [==============================] - 15s 722ms/step - loss: 0.6012 - categorical_acc
uracy: 0.7282 - val_loss: 0.4864 - val_categorical_accuracy: 0.7800
Epoch 65/100
21/21 [==============================] - 15s 692ms/step - loss: 0.6084 - categorical_acc
uracy: 0.7233 - val_loss: 0.7780 - val_categorical_accuracy: 0.6200
Epoch 66/100
21/21 [==============================] - 14s 682ms/step - loss: 0.6100 - categorical_acc
uracy: 0.7621 - val_loss: 0.9396 - val_categorical_accuracy: 0.5600
Epoch 67/100
21/21 [==============================] - 15s 722ms/step - loss: 0.5931 - categorical_acc
uracy: 0.7282 - val_loss: 0.8330 - val_categorical_accuracy: 0.6200
Epoch 68/100
21/21 [==============================] - 14s 679ms/step - loss: 0.5809 - categorical_acc
uracy: 0.7621 - val_loss: 0.7627 - val_categorical_accuracy: 0.6400
Epoch 69/100
21/21 [==============================] - 14s 655ms/step - loss: 0.5396 - categorical_acc
uracy: 0.8058 - val_loss: 0.8683 - val_categorical_accuracy: 0.6000
Epoch 70/100
21/21 [==============================] - 14s 682ms/step - loss: 0.6343 - categorical_acc
uracy: 0.7184 - val_loss: 1.2533 - val_categorical_accuracy: 0.5400
Epoch 71/100
21/21 [==============================] - 14s 679ms/step - loss: 0.6970 - categorical_acc
uracy: 0.6748 - val_loss: 0.7456 - val_categorical_accuracy: 0.6400
Epoch 72/100
21/21 [==============================] - 14s 682ms/step - loss: 0.5303 - categorical_acc
uracy: 0.7816 - val_loss: 0.8743 - val_categorical_accuracy: 0.6600
Epoch 73/100
21/21 [==============================] - 14s 683ms/step - loss: 0.5717 - categorical_acc
uracy: 0.7427 - val_loss: 0.5851 - val_categorical_accuracy: 0.7000
Epoch 74/100
21/21 [==============================] - 14s 687ms/step - loss: 0.5119 - categorical_acc
uracy: 0.7621 - val_loss: 0.5795 - val_categorical_accuracy: 0.7200
Epoch 75/100
21/21 [==============================] - 14s 675ms/step - loss: 0.5298 - categorical_acc
uracy: 0.7961 - val_loss: 0.6762 - val_categorical_accuracy: 0.7000
Epoch 76/100
21/21 [==============================] - 14s 684ms/step - loss: 0.4929 - categorical_acc
uracy: 0.8107 - val_loss: 0.6786 - val_categorical_accuracy: 0.7200
Epoch 77/100
21/21 [==============================] - 14s 675ms/step - loss: 0.5242 - categorical_acc
uracy: 0.7767 - val_loss: 0.8066 - val_categorical_accuracy: 0.6400
Epoch 78/100
21/21 [==============================] - 14s 688ms/step - loss: 0.5971 - categorical_acc
uracy: 0.7864 - val_loss: 1.1145 - val_categorical_accuracy: 0.6200
Epoch 79/100
21/21 [==============================] - 14s 680ms/step - loss: 0.5152 - categorical_acc
uracy: 0.7621 - val_loss: 0.4777 - val_categorical_accuracy: 0.8400
Epoch 80/100
21/21 [==============================] - 14s 658ms/step - loss: 0.5537 - categorical_acc
uracy: 0.7864 - val_loss: 0.5568 - val_categorical_accuracy: 0.7600
Epoch 81/100
21/21 [==============================] - 14s 688ms/step - loss: 0.5500 - categorical_acc
uracy: 0.7816 - val_loss: 0.6957 - val_categorical_accuracy: 0.6600
Epoch 82/100
21/21 [==============================] - 14s 650ms/step - loss: 0.4785 - categorical_acc
```

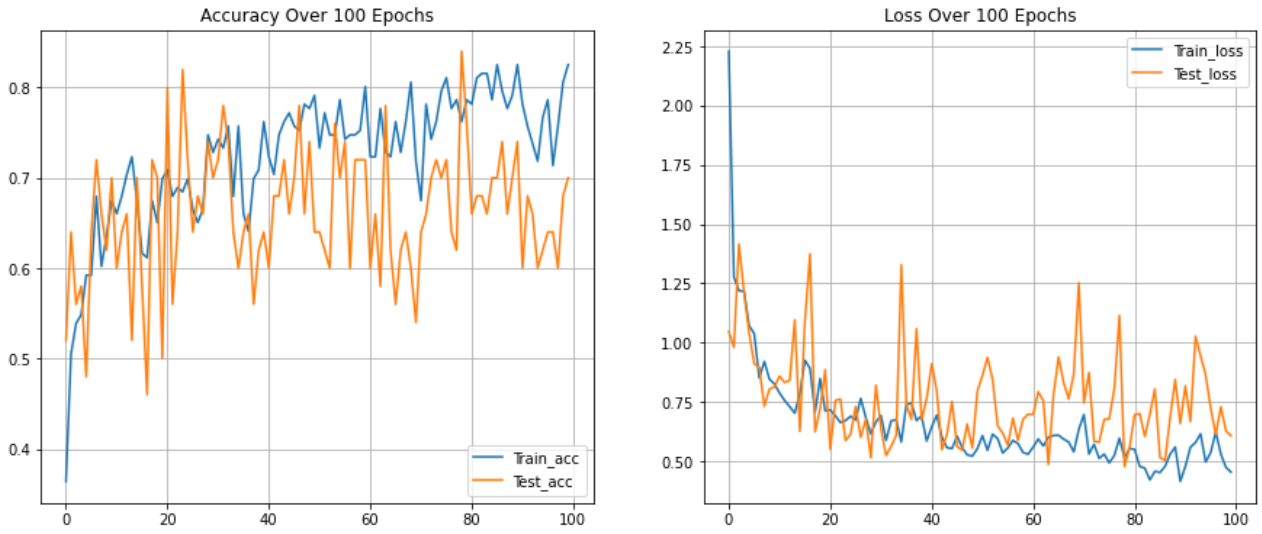
```
uracy: 0.8107 - val_loss: 0.7011 - val_categorical_accuracy: 0.6800
Epoch 83/100
21/21 [==============================] - 14s 670ms/step - loss: 0.4707 - categorical_acc
uracy: 0.8155 - val_loss: 0.6044 - val_categorical_accuracy: 0.6800
Epoch 84/100
21/21 [==============================] - 14s 683ms/step - loss: 0.4212 - categorical_acc
uracy: 0.8155 - val_loss: 0.6969 - val_categorical_accuracy: 0.6600
Epoch 85/100
21/21 [==============================] - 14s 679ms/step - loss: 0.4575 - categorical_acc
uracy: 0.7864 - val_loss: 0.8051 - val_categorical_accuracy: 0.7000
Epoch 86/100
21/21 [==============================] - 14s 679ms/step - loss: 0.4523 - categorical_acc
uracy: 0.8252 - val_loss: 0.5153 - val_categorical_accuracy: 0.7000
Epoch 87/100
21/21 [==============================] - 14s 675ms/step - loss: 0.4786 - categorical_acc
uracy: 0.7961 - val_loss: 0.5039 - val_categorical_accuracy: 0.7400
Epoch 88/100
21/21 [==============================] - 14s 675ms/step - loss: 0.5296 - categorical_acc
uracy: 0.7767 - val_loss: 0.6858 - val_categorical_accuracy: 0.6600
Epoch 89/100
21/21 [==============================] - 15s 687ms/step - loss: 0.5598 - categorical_acc
uracy: 0.7913 - val_loss: 0.8444 - val_categorical_accuracy: 0.7000
Epoch 90/100
21/21 [==============================] - 14s 674ms/step - loss: 0.4149 - categorical_acc
uracy: 0.8252 - val_loss: 0.6589 - val_categorical_accuracy: 0.7400
Epoch 91/100
21/21 [==============================] - 14s 675ms/step - loss: 0.4783 - categorical_acc
uracy: 0.7816 - val_loss: 0.8178 - val_categorical_accuracy: 0.6000
Epoch 92/100
21/21 [==============================] - 14s 680ms/step - loss: 0.5592 - categorical_acc
uracy: 0.7573 - val_loss: 0.6674 - val_categorical_accuracy: 0.6800
Epoch 93/100
21/21 [==============================] - 14s 671ms/step - loss: 0.5789 - categorical_acc
uracy: 0.7379 - val_loss: 1.0272 - val_categorical_accuracy: 0.6600
Epoch 94/100
21/21 [==============================] - 14s 659ms/step - loss: 0.6158 - categorical_acc
uracy: 0.7184 - val_loss: 0.9452 - val_categorical_accuracy: 0.6000
Epoch 95/100
21/21 [==============================] - 14s 679ms/step - loss: 0.4965 - categorical_acc
uracy: 0.7670 - val_loss: 0.8646 - val_categorical_accuracy: 0.6200
Epoch 96/100
21/21 [==============================] - 15s 695ms/step - loss: 0.5369 - categorical_acc
uracy: 0.7864 - val_loss: 0.7234 - val_categorical_accuracy: 0.6400
Epoch 97/100
21/21 [==============================] - 14s 681ms/step - loss: 0.6235 - categorical_acc
uracy: 0.7136 - val_loss: 0.6121 - val_categorical_accuracy: 0.6400
Epoch 98/100
21/21 [==============================] - 14s 686ms/step - loss: 0.5301 - categorical_acc
uracy: 0.7573 - val_loss: 0.7294 - val_categorical_accuracy: 0.6000
Epoch 99/100
21/21 [==============================] - 14s 680ms/step - loss: 0.4741 - categorical_acc
uracy: 0.8058 - val_loss: 0.6275 - val_categorical_accuracy: 0.6800
Epoch 100/100
21/21 [==============================] - 14s 685ms/step - loss: 0.4540 - categorical_acc
uracy: 0.8252 - val_loss: 0.6081 - val_categorical_accuracy: 0.7000
```

[5 points] Plot Accuracy and Loss During Training

In [9]:

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

```
fig, (ax1, ax2) = plt.subplots(1, 2)
fig.set_figheight(6)
fig.set_figwidth(15)
ax1.plot(res.history['categorical_accuracy'])
ax1.plot(res.history['val_categorical_accuracy'])
ax1.set_title('Accuracy Over ' + str(NUM_EPOCHS) + ' Epochs')
ax1.legend(['Train_acc', 'Test_acc'], loc='lower right')
ax1.grid(True)
ax2.set_title('Loss Over ' + str(NUM_EPOCHS) + ' Epochs')
ax2.plot(res.history['loss'])
ax2.plot(res.history['val_loss'])
ax2.legend(['Train_loss', 'Test_loss'], loc='upper right')
ax2.grid(True)
plt.show()
```



Testing Model

In [10]:

```
test_datagen = ImageDataGenerator(rescale=1. / 255)

eval_generator = test_datagen.flow_from_directory(TEST_DIR,target_size=IMAGE_SIZE,
                                                  batch_size=1,shuffle=True,seed=42,cla
eval_generator.reset()
print(len(eval_generator))
x = model.evaluate_generator(eval_generator,steps = np.ceil(len(eval_generator)),
                             use_multiprocessing = False,verbose = 1,workers=1)
print('Test loss:' , x[0])
print('Test accuracy:',x[1])
```

```
Found 36 images belonging to 4 classes.
36
 2/36 [>.............................] - ETA: 2s - loss: 3.9921 - categorical_accuracy:
0.5000
C:\ProgramData\Anaconda3\lib\site-packages\keras\engine\training.py:2006: UserWarning: `
Model.evaluate_generator` is deprecated and will be removed in a future version. Please
use `Model.evaluate`, which supports generators.
  warnings.warn('`Model.evaluate_generator` is deprecated and '
36/36 [==============================] - 2s 61ms/step - loss: 0.7604 - categorical_accur
acy: 0.6944
Test loss: 0.7604448795318604
Test accuracy: 0.6944444179534912
```

[10 points] TSNE Plot

t-Distributed Stochastic Neighbor Embedding (t-SNE) is a widely used technique for dimensionality reduction that is particularly well suited for the visualization of high-dimensional datasets. After training is complete, extract features from a specific deep layer of your choice, use t-SNE to reduce the dimensionality of your extracted features to 2 dimensions and plot the resulting 2D features.

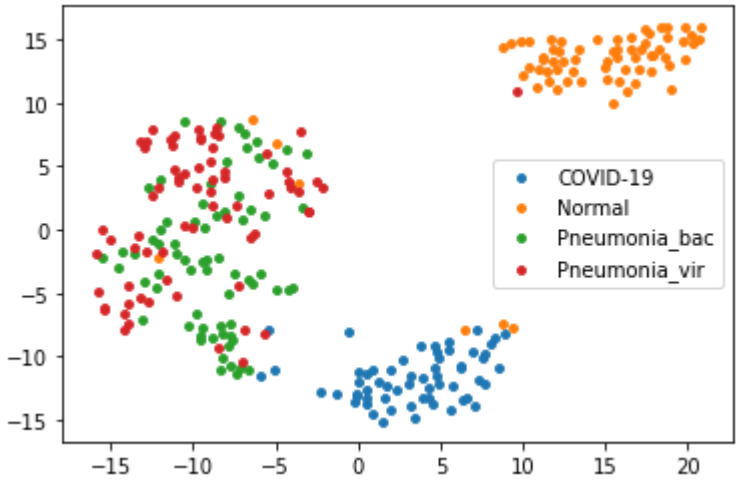
In [15]:
```
from sklearn.manifold import TSNE

intermediate_layer_model = models.Model(inputs=model.input,
                                        outputs=model.get_layer('feature_dense').output

tsne_eval_generator = test_datagen.flow_from_directory(DATASET_PATH,target_size=IMAGE_S
                                                       batch_size=1,shuffle=True,seed=42,cla

raise NotImplementedError("Extract features from the tsne_data_generator and fit a t-SN
                          "and plot the resulting 2D features of the four classes.")
```

```
Found 270 images belonging to 4 classes.
{'covid': 0, 'normal': 1, 'pneumonia_bac': 2, 'pneumonia_vir': 3}
Extracting features for 270 images.
270/270 [==============================] - 71s 265ms/step
Training TSNE model.
```



Attempt 2: Revising the vgg16 model with additional layers

[10 points] Build Model

Hint: Starting from a pre-trained model typically helps performance on a new task, e.g. starting with weights obtained by training on ImageNet.

In [106…
```
vgg16 = tf.keras.applications.VGG16(weights='imagenet', include_top=False, input_shape=
vgg16.trainable = False
model = tf.keras.Sequential([
    vgg16,
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(500, activation='relu'),
```

```
    tf.keras.layers.Dropout(rate=0.2),
    tf.keras.layers.Dense(125, activation='relu'),
    tf.keras.layers.Dropout(rate=0.2),
    tf.keras.layers.Dense(4, activation='softmax')
])
model.compile(optimizer = tf.keras.optimizers.Adam(learning_rate=1e-5), loss = 'categor
              metrics = ['categorical_accuracy'])
```

In [107…

```
model.summary()
```

```
Model: "sequential_25"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
vgg16 (Functional)           (None, 7, 7, 512)         14714688
_________________________________________________________________
flatten_25 (Flatten)         (None, 25088)             0
_________________________________________________________________
dense_76 (Dense)             (None, 500)               12544500
_________________________________________________________________
dropout_49 (Dropout)         (None, 500)               0
_________________________________________________________________
dense_77 (Dense)             (None, 125)               62625
_________________________________________________________________
dropout_50 (Dropout)         (None, 125)               0
_________________________________________________________________
dense_78 (Dense)             (None, 4)                 504
=================================================================
Total params: 27,322,317
Trainable params: 12,607,629
Non-trainable params: 14,714,688
_________________________________________________________________
```

[5 points] Train Model

In [108…

```
#FIT MODEL
print(len(train_batches))
print(len(valid_batches))


STEP_SIZE_TRAIN=train_batches.n//train_batches.batch_size
STEP_SIZE_VALID=valid_batches.n//valid_batches.batch_size



res = model.fit(train_batches, epochs=NUM_EPOCHS, steps_per_epoch=STEP_SIZE_TRAIN, \
          validation_data=valid_batches, validation_steps=STEP_SIZE_VALID)
```

```
22
6
Epoch 1/100
21/21 [==============================] - 16s 730ms/step - loss: 1.5256 - categorical_acc
uracy: 0.2571 - val_loss: 1.3473 - val_categorical_accuracy: 0.2800
Epoch 2/100
21/21 [==============================] - 15s 736ms/step - loss: 1.3996 - categorical_acc
uracy: 0.2864 - val_loss: 1.3457 - val_categorical_accuracy: 0.4400
Epoch 3/100
21/21 [==============================] - 15s 737ms/step - loss: 1.3743 - categorical_acc
```

```
uracy: 0.3058 - val_loss: 1.2964 - val_categorical_accuracy: 0.4400
Epoch 4/100
21/21 [==============================] - 17s 793ms/step - loss: 1.3410 - categorical_acc
uracy: 0.3495 - val_loss: 1.2727 - val_categorical_accuracy: 0.4000
Epoch 5/100
21/21 [==============================] - 17s 788ms/step - loss: 1.3080 - categorical_acc
uracy: 0.3952 - val_loss: 1.2660 - val_categorical_accuracy: 0.4000
Epoch 6/100
21/21 [==============================] - 16s 776ms/step - loss: 1.3034 - categorical_acc
uracy: 0.3738 - val_loss: 1.1904 - val_categorical_accuracy: 0.5400
Epoch 7/100
21/21 [==============================] - 16s 785ms/step - loss: 1.2384 - categorical_acc
uracy: 0.4466 - val_loss: 1.1790 - val_categorical_accuracy: 0.4400
Epoch 8/100
21/21 [==============================] - 16s 772ms/step - loss: 1.2014 - categorical_acc
uracy: 0.4369 - val_loss: 1.1511 - val_categorical_accuracy: 0.4400
Epoch 9/100
21/21 [==============================] - 16s 766ms/step - loss: 1.1721 - categorical_acc
uracy: 0.4903 - val_loss: 1.1022 - val_categorical_accuracy: 0.5800
Epoch 10/100
21/21 [==============================] - 16s 761ms/step - loss: 1.1569 - categorical_acc
uracy: 0.5291 - val_loss: 1.0469 - val_categorical_accuracy: 0.6200
Epoch 11/100
21/21 [==============================] - 16s 775ms/step - loss: 1.1385 - categorical_acc
uracy: 0.4757 - val_loss: 1.0814 - val_categorical_accuracy: 0.5200
Epoch 12/100
21/21 [==============================] - 16s 765ms/step - loss: 1.0762 - categorical_acc
uracy: 0.5728 - val_loss: 1.0509 - val_categorical_accuracy: 0.4800
Epoch 13/100
21/21 [==============================] - 16s 771ms/step - loss: 1.1088 - categorical_acc
uracy: 0.5437 - val_loss: 1.0136 - val_categorical_accuracy: 0.5400
Epoch 14/100
21/21 [==============================] - 17s 783ms/step - loss: 1.0383 - categorical_acc
uracy: 0.5680 - val_loss: 0.9926 - val_categorical_accuracy: 0.6200
Epoch 15/100
21/21 [==============================] - 17s 791ms/step - loss: 1.0628 - categorical_acc
uracy: 0.5049 - val_loss: 0.9945 - val_categorical_accuracy: 0.5000
Epoch 16/100
21/21 [==============================] - 16s 770ms/step - loss: 1.0770 - categorical_acc
uracy: 0.5049 - val_loss: 0.9241 - val_categorical_accuracy: 0.6200
Epoch 17/100
21/21 [==============================] - 16s 772ms/step - loss: 0.9833 - categorical_acc
uracy: 0.6068 - val_loss: 0.9012 - val_categorical_accuracy: 0.6400
Epoch 18/100
21/21 [==============================] - 16s 766ms/step - loss: 0.9968 - categorical_acc
uracy: 0.5243 - val_loss: 1.0218 - val_categorical_accuracy: 0.4800
Epoch 19/100
21/21 [==============================] - 17s 797ms/step - loss: 1.0115 - categorical_acc
uracy: 0.5922 - val_loss: 0.9368 - val_categorical_accuracy: 0.6000
Epoch 20/100
21/21 [==============================] - 17s 783ms/step - loss: 0.9791 - categorical_acc
uracy: 0.5680 - val_loss: 0.9529 - val_categorical_accuracy: 0.5200
Epoch 21/100
21/21 [==============================] - 17s 788ms/step - loss: 1.0664 - categorical_acc
uracy: 0.5243 - val_loss: 0.9011 - val_categorical_accuracy: 0.5600
Epoch 22/100
21/21 [==============================] - 17s 794ms/step - loss: 0.9774 - categorical_acc
uracy: 0.5922 - val_loss: 0.8851 - val_categorical_accuracy: 0.6800
Epoch 23/100
21/21 [==============================] - 17s 798ms/step - loss: 0.9305 - categorical_acc
```

```
uracy: 0.6019 - val_loss: 0.8752 - val_categorical_accuracy: 0.6400
Epoch 24/100
21/21 [==============================] - 16s 793ms/step - loss: 0.9641 - categorical_acc
uracy: 0.6165 - val_loss: 0.8295 - val_categorical_accuracy: 0.6600
Epoch 25/100
21/21 [==============================] - 17s 789ms/step - loss: 0.9490 - categorical_acc
uracy: 0.5825 - val_loss: 0.9095 - val_categorical_accuracy: 0.6000
Epoch 26/100
21/21 [==============================] - 17s 792ms/step - loss: 0.9637 - categorical_acc
uracy: 0.5777 - val_loss: 0.8205 - val_categorical_accuracy: 0.7600
Epoch 27/100
21/21 [==============================] - 17s 790ms/step - loss: 0.9420 - categorical_acc
uracy: 0.5922 - val_loss: 0.9387 - val_categorical_accuracy: 0.5200
Epoch 28/100
21/21 [==============================] - 17s 804ms/step - loss: 0.9356 - categorical_acc
uracy: 0.5810 - val_loss: 0.8439 - val_categorical_accuracy: 0.6800
Epoch 29/100
21/21 [==============================] - 16s 782ms/step - loss: 0.8930 - categorical_acc
uracy: 0.6456 - val_loss: 0.8396 - val_categorical_accuracy: 0.5800
Epoch 30/100
21/21 [==============================] - 17s 813ms/step - loss: 0.9135 - categorical_acc
uracy: 0.5905 - val_loss: 0.8276 - val_categorical_accuracy: 0.6000
Epoch 31/100
21/21 [==============================] - 17s 795ms/step - loss: 0.8680 - categorical_acc
uracy: 0.6408 - val_loss: 0.8018 - val_categorical_accuracy: 0.6800
Epoch 32/100
21/21 [==============================] - 16s 785ms/step - loss: 0.8336 - categorical_acc
uracy: 0.6845 - val_loss: 0.8046 - val_categorical_accuracy: 0.7000
Epoch 33/100
21/21 [==============================] - 15s 725ms/step - loss: 0.8228 - categorical_acc
uracy: 0.6845 - val_loss: 0.8323 - val_categorical_accuracy: 0.6600
Epoch 34/100
21/21 [==============================] - 16s 762ms/step - loss: 0.8506 - categorical_acc
uracy: 0.6214 - val_loss: 0.8489 - val_categorical_accuracy: 0.6400
Epoch 35/100
21/21 [==============================] - 16s 780ms/step - loss: 0.8518 - categorical_acc
uracy: 0.6359 - val_loss: 0.8607 - val_categorical_accuracy: 0.5800
Epoch 36/100
21/21 [==============================] - 16s 747ms/step - loss: 0.8660 - categorical_acc
uracy: 0.6408 - val_loss: 0.9271 - val_categorical_accuracy: 0.5400
Epoch 37/100
21/21 [==============================] - 16s 742ms/step - loss: 0.8793 - categorical_acc
uracy: 0.5777 - val_loss: 0.8072 - val_categorical_accuracy: 0.6000
Epoch 38/100
21/21 [==============================] - 16s 774ms/step - loss: 0.8588 - categorical_acc
uracy: 0.6165 - val_loss: 0.7877 - val_categorical_accuracy: 0.6400
Epoch 39/100
21/21 [==============================] - 16s 772ms/step - loss: 0.8651 - categorical_acc
uracy: 0.6019 - val_loss: 0.7711 - val_categorical_accuracy: 0.6200
Epoch 40/100
21/21 [==============================] - 17s 803ms/step - loss: 0.8522 - categorical_acc
uracy: 0.6214 - val_loss: 0.8392 - val_categorical_accuracy: 0.6200
Epoch 41/100
21/21 [==============================] - 15s 718ms/step - loss: 0.8181 - categorical_acc
uracy: 0.6553 - val_loss: 0.8123 - val_categorical_accuracy: 0.6000
Epoch 42/100
21/21 [==============================] - 17s 795ms/step - loss: 0.8270 - categorical_acc
uracy: 0.6699 - val_loss: 0.7008 - val_categorical_accuracy: 0.6800
Epoch 43/100
21/21 [==============================] - 18s 875ms/step - loss: 0.8361 - categorical_acc
```

```
uracy: 0.6262 - val_loss: 0.7835 - val_categorical_accuracy: 0.5800
Epoch 44/100
21/21 [==============================] - 18s 868ms/step - loss: 0.8245 - categorical_acc
uracy: 0.6762 - val_loss: 0.8003 - val_categorical_accuracy: 0.6400
Epoch 45/100
21/21 [==============================] - 17s 806ms/step - loss: 0.8592 - categorical_acc
uracy: 0.6359 - val_loss: 0.8018 - val_categorical_accuracy: 0.6000
Epoch 46/100
21/21 [==============================] - 16s 762ms/step - loss: 0.8045 - categorical_acc
uracy: 0.6796 - val_loss: 0.7967 - val_categorical_accuracy: 0.6000
Epoch 47/100
21/21 [==============================] - 17s 816ms/step - loss: 0.8124 - categorical_acc
uracy: 0.6650 - val_loss: 0.7897 - val_categorical_accuracy: 0.6000
Epoch 48/100
21/21 [==============================] - 17s 836ms/step - loss: 0.8001 - categorical_acc
uracy: 0.6650 - val_loss: 0.7925 - val_categorical_accuracy: 0.6000
Epoch 49/100
21/21 [==============================] - 18s 865ms/step - loss: 0.7459 - categorical_acc
uracy: 0.6408 - val_loss: 0.7188 - val_categorical_accuracy: 0.6600
Epoch 50/100
21/21 [==============================] - 16s 750ms/step - loss: 0.8010 - categorical_acc
uracy: 0.6748 - val_loss: 0.9118 - val_categorical_accuracy: 0.5200
Epoch 51/100
21/21 [==============================] - 17s 810ms/step - loss: 0.7472 - categorical_acc
uracy: 0.6796 - val_loss: 0.7118 - val_categorical_accuracy: 0.6600
Epoch 52/100
21/21 [==============================] - 18s 832ms/step - loss: 0.8241 - categorical_acc
uracy: 0.6381 - val_loss: 0.8619 - val_categorical_accuracy: 0.6000
Epoch 53/100
21/21 [==============================] - 18s 868ms/step - loss: 0.8229 - categorical_acc
uracy: 0.6456 - val_loss: 0.8276 - val_categorical_accuracy: 0.6200
Epoch 54/100
21/21 [==============================] - 17s 820ms/step - loss: 0.8040 - categorical_acc
uracy: 0.6952 - val_loss: 0.7786 - val_categorical_accuracy: 0.6400
Epoch 55/100
21/21 [==============================] - 17s 827ms/step - loss: 0.8307 - categorical_acc
uracy: 0.6262 - val_loss: 0.7834 - val_categorical_accuracy: 0.5400
Epoch 56/100
21/21 [==============================] - 18s 846ms/step - loss: 0.7791 - categorical_acc
uracy: 0.7039 - val_loss: 0.7350 - val_categorical_accuracy: 0.6600
Epoch 57/100
21/21 [==============================] - 18s 860ms/step - loss: 0.7337 - categorical_acc
uracy: 0.6990 - val_loss: 0.7322 - val_categorical_accuracy: 0.6400
Epoch 58/100
21/21 [==============================] - 18s 856ms/step - loss: 0.7646 - categorical_acc
uracy: 0.7039 - val_loss: 0.7506 - val_categorical_accuracy: 0.7000
Epoch 59/100
21/21 [==============================] - 19s 878ms/step - loss: 0.7742 - categorical_acc
uracy: 0.6650 - val_loss: 0.7285 - val_categorical_accuracy: 0.6400
Epoch 60/100
21/21 [==============================] - 18s 831ms/step - loss: 0.6988 - categorical_acc
uracy: 0.6845 - val_loss: 0.7820 - val_categorical_accuracy: 0.5600
Epoch 61/100
21/21 [==============================] - 18s 863ms/step - loss: 0.7218 - categorical_acc
uracy: 0.7039 - val_loss: 0.7406 - val_categorical_accuracy: 0.6400
Epoch 62/100
21/21 [==============================] - 19s 899ms/step - loss: 0.7581 - categorical_acc
uracy: 0.6553 - val_loss: 0.7649 - val_categorical_accuracy: 0.5800
Epoch 63/100
21/21 [==============================] - 19s 884ms/step - loss: 0.7337 - categorical_acc
```

```
uracy: 0.6602 - val_loss: 0.7345 - val_categorical_accuracy: 0.6600
Epoch 64/100
21/21 [==============================] - 19s 904ms/step - loss: 0.6880 - categorical_acc
uracy: 0.7039 - val_loss: 0.6959 - val_categorical_accuracy: 0.7000
Epoch 65/100
21/21 [==============================] - 18s 872ms/step - loss: 0.7359 - categorical_acc
uracy: 0.6990 - val_loss: 0.6780 - val_categorical_accuracy: 0.6400
Epoch 66/100
21/21 [==============================] - 18s 874ms/step - loss: 0.6784 - categorical_acc
uracy: 0.7476 - val_loss: 0.7135 - val_categorical_accuracy: 0.6800
Epoch 67/100
21/21 [==============================] - 19s 881ms/step - loss: 0.6953 - categorical_acc
uracy: 0.7087 - val_loss: 0.6518 - val_categorical_accuracy: 0.6600
Epoch 68/100
21/21 [==============================] - 20s 936ms/step - loss: 0.8135 - categorical_acc
uracy: 0.6068 - val_loss: 0.8039 - val_categorical_accuracy: 0.5600
Epoch 69/100
21/21 [==============================] - 19s 907ms/step - loss: 0.7258 - categorical_acc
uracy: 0.6990 - val_loss: 0.7028 - val_categorical_accuracy: 0.7600
Epoch 70/100
21/21 [==============================] - 19s 885ms/step - loss: 0.7403 - categorical_acc
uracy: 0.6748 - val_loss: 0.7585 - val_categorical_accuracy: 0.7200
Epoch 71/100
21/21 [==============================] - 19s 906ms/step - loss: 0.7517 - categorical_acc
uracy: 0.6796 - val_loss: 0.7324 - val_categorical_accuracy: 0.7000
Epoch 72/100
21/21 [==============================] - 16s 767ms/step - loss: 0.7306 - categorical_acc
uracy: 0.6942 - val_loss: 0.6031 - val_categorical_accuracy: 0.7200
Epoch 73/100
21/21 [==============================] - 16s 748ms/step - loss: 0.6886 - categorical_acc
uracy: 0.7379 - val_loss: 0.7213 - val_categorical_accuracy: 0.5400
Epoch 74/100
21/21 [==============================] - 16s 746ms/step - loss: 0.7387 - categorical_acc
uracy: 0.6893 - val_loss: 0.7330 - val_categorical_accuracy: 0.6200
Epoch 75/100
21/21 [==============================] - 16s 753ms/step - loss: 0.7185 - categorical_acc
uracy: 0.6650 - val_loss: 0.6559 - val_categorical_accuracy: 0.7600
Epoch 76/100
21/21 [==============================] - 16s 769ms/step - loss: 0.7401 - categorical_acc
uracy: 0.6990 - val_loss: 0.7027 - val_categorical_accuracy: 0.5800
Epoch 77/100
21/21 [==============================] - 16s 758ms/step - loss: 0.6770 - categorical_acc
uracy: 0.7621 - val_loss: 0.6649 - val_categorical_accuracy: 0.7600
Epoch 78/100
21/21 [==============================] - 16s 753ms/step - loss: 0.7340 - categorical_acc
uracy: 0.6845 - val_loss: 0.6997 - val_categorical_accuracy: 0.6400
Epoch 79/100
21/21 [==============================] - 16s 764ms/step - loss: 0.7009 - categorical_acc
uracy: 0.7330 - val_loss: 0.7243 - val_categorical_accuracy: 0.5800
Epoch 80/100
21/21 [==============================] - 16s 783ms/step - loss: 0.7129 - categorical_acc
uracy: 0.6990 - val_loss: 0.8181 - val_categorical_accuracy: 0.5800
Epoch 81/100
21/21 [==============================] - 16s 768ms/step - loss: 0.7428 - categorical_acc
uracy: 0.6942 - val_loss: 0.6730 - val_categorical_accuracy: 0.7000
Epoch 82/100
21/21 [==============================] - 16s 781ms/step - loss: 0.7018 - categorical_acc
uracy: 0.6942 - val_loss: 0.7864 - val_categorical_accuracy: 0.6200
Epoch 83/100
21/21 [==============================] - 17s 790ms/step - loss: 0.7019 - categorical_acc
```

```
uracy: 0.6990 - val_loss: 0.6251 - val_categorical_accuracy: 0.7000
Epoch 84/100
21/21 [==============================] - 17s 792ms/step - loss: 0.7014 - categorical_acc
uracy: 0.6942 - val_loss: 0.7933 - val_categorical_accuracy: 0.6600
Epoch 85/100
21/21 [==============================] - 16s 781ms/step - loss: 0.6824 - categorical_acc
uracy: 0.7087 - val_loss: 0.6870 - val_categorical_accuracy: 0.6400
Epoch 86/100
21/21 [==============================] - 16s 771ms/step - loss: 0.7167 - categorical_acc
uracy: 0.6893 - val_loss: 0.7381 - val_categorical_accuracy: 0.6000
Epoch 87/100
21/21 [==============================] - 16s 752ms/step - loss: 0.7577 - categorical_acc
uracy: 0.6359 - val_loss: 0.7317 - val_categorical_accuracy: 0.5800
Epoch 88/100
21/21 [==============================] - 16s 761ms/step - loss: 0.6477 - categorical_acc
uracy: 0.7427 - val_loss: 0.6850 - val_categorical_accuracy: 0.6600
Epoch 89/100
21/21 [==============================] - 15s 734ms/step - loss: 0.6786 - categorical_acc
uracy: 0.7184 - val_loss: 0.5812 - val_categorical_accuracy: 0.7800
Epoch 90/100
21/21 [==============================] - 15s 728ms/step - loss: 0.6739 - categorical_acc
uracy: 0.6796 - val_loss: 0.7188 - val_categorical_accuracy: 0.6200
Epoch 91/100
21/21 [==============================] - 15s 731ms/step - loss: 0.6774 - categorical_acc
uracy: 0.6942 - val_loss: 0.6916 - val_categorical_accuracy: 0.7000
Epoch 92/100
21/21 [==============================] - 15s 731ms/step - loss: 0.6837 - categorical_acc
uracy: 0.7136 - val_loss: 0.7494 - val_categorical_accuracy: 0.6000
Epoch 93/100
21/21 [==============================] - 16s 748ms/step - loss: 0.6728 - categorical_acc
uracy: 0.7087 - val_loss: 0.6472 - val_categorical_accuracy: 0.7000
Epoch 94/100
21/21 [==============================] - 16s 764ms/step - loss: 0.6821 - categorical_acc
uracy: 0.7233 - val_loss: 0.6472 - val_categorical_accuracy: 0.7600
Epoch 95/100
21/21 [==============================] - 16s 742ms/step - loss: 0.7226 - categorical_acc
uracy: 0.6619 - val_loss: 0.7326 - val_categorical_accuracy: 0.6600
Epoch 96/100
21/21 [==============================] - 17s 780ms/step - loss: 0.6432 - categorical_acc
uracy: 0.7670 - val_loss: 0.6320 - val_categorical_accuracy: 0.7400
Epoch 97/100
21/21 [==============================] - 16s 764ms/step - loss: 0.6542 - categorical_acc
uracy: 0.7282 - val_loss: 0.6764 - val_categorical_accuracy: 0.6600
Epoch 98/100
21/21 [==============================] - 16s 747ms/step - loss: 0.6859 - categorical_acc
uracy: 0.7379 - val_loss: 0.6319 - val_categorical_accuracy: 0.7400
Epoch 99/100
21/21 [==============================] - 16s 748ms/step - loss: 0.6761 - categorical_acc
uracy: 0.7330 - val_loss: 0.7390 - val_categorical_accuracy: 0.6600
Epoch 100/100
21/21 [==============================] - 16s 759ms/step - loss: 0.7077 - categorical_acc
uracy: 0.6845 - val_loss: 0.6197 - val_categorical_accuracy: 0.7200
```

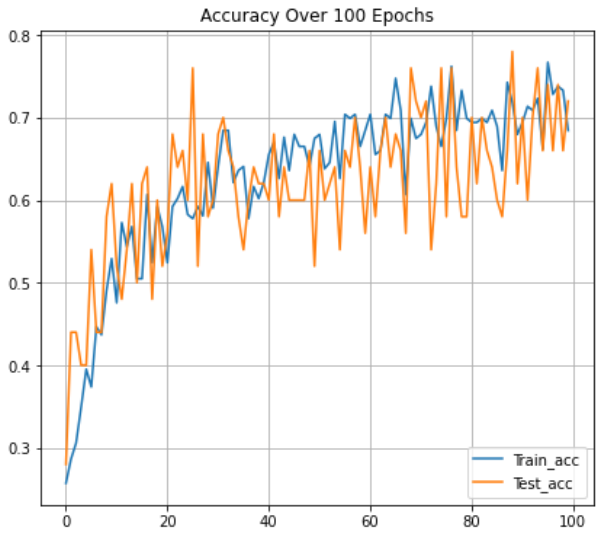
[5 points] Plot Accuracy and Loss During Training

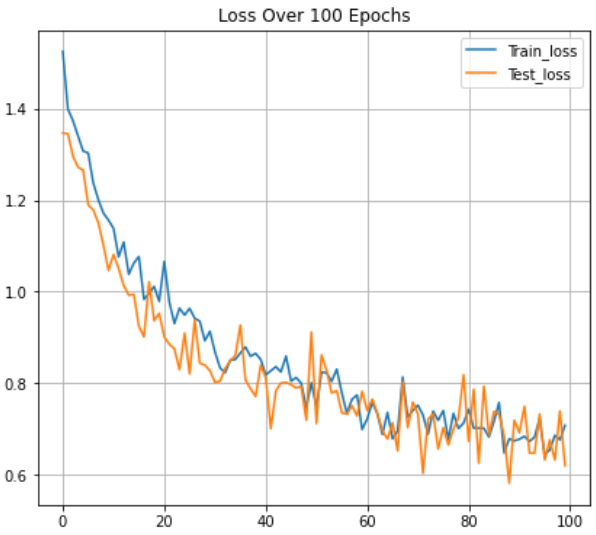
In [111…

```
import matplotlib.pyplot as plt

fig, (ax1, ax2) = plt.subplots(1, 2)
fig.set_figheight(6)
```

```
fig.set_figwidth(15)
ax1.plot(res.history['categorical_accuracy'])
ax1.plot(res.history['val_categorical_accuracy'])
ax1.set_title('Accuracy Over ' + str(NUM_EPOCHS) + ' Epochs')
ax1.legend(['Train_acc', 'Test_acc'], loc='lower right')
ax1.grid(True)
ax2.set_title('Loss Over ' + str(NUM_EPOCHS) + ' Epochs')
ax2.plot(res.history['loss'])
ax2.plot(res.history['val_loss'])
ax2.legend(['Train_loss', 'Test_loss'], loc='upper right')
ax2.grid(True)
plt.show()
```





Testing Model

In [112…

```
test_datagen = ImageDataGenerator(rescale=1. / 255)

eval_generator = test_datagen.flow_from_directory(TEST_DIR,target_size=IMAGE_SIZE,
                                                  batch_size=1,shuffle=True,seed=42,cla
eval_generator.reset()
print(len(eval_generator))
x = model.evaluate_generator(eval_generator,steps = np.ceil(len(eval_generator)),
                             use_multiprocessing = False,verbose = 1,workers=1)
print('Test loss:' , x[0])
print('Test accuracy:',x[1])
```

```
Found 36 images belonging to 4 classes.
36
36/36 [==============================] - 3s 82ms/step - loss: 0.8460 - categorical_accur
acy: 0.6389
Test loss: 0.8460082411766052
Test accuracy: 0.6388888955116272
```

Attempt 3: Try generating more fake data with data augmentation

Generate Training and Validation Batches

In [115…

```
train_datagen = ImageDataGenerator(rescale=1./255,rotation_range=50,featurewise_center
```

```
                                    featurewise_std_normalization = True,width_shift_ran
                                    height_shift_range=0.2,shear_range=0.25,zoom_range=0
                                    zca_whitening = True,channel_shift_range = 20,
                                    horizontal_flip = True,vertical_flip = True,
                                    validation_split = 0.2,fill_mode='constant')


train_batches = train_datagen.flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                  shuffle=True,batch_size=BATCH_SIZE,
                                                  subset = "training",seed=42,
                                                  class_mode="categorical")

valid_batches = train_datagen.flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                  shuffle=True,batch_size=BATCH_SIZE,
                                                  subset = "validation",
                                                  seed=42,class_mode="categorical")
```

```
Found 216 images belonging to 4 classes.
Found 54 images belonging to 4 classes.
```

[10 points] Build Model

Hint: Starting from a pre-trained model typically helps performance on a new task, e.g. starting with weights obtained by training on ImageNet.

In [123…

```
vgg16 = tf.keras.applications.VGG16(weights='imagenet', include_top=False, input_shape=
vgg16.trainable = False
model = tf.keras.Sequential([
    vgg16,
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(128, activation='relu'),
    tf.keras.layers.Dense(4, activation='softmax')
])
model.compile(optimizer = tf.keras.optimizers.Adam(learning_rate=1e-5),
              loss = 'categorical_crossentropy', metrics = ['categorical_accuracy'])
```

In [124…

```
model.summary()
```

```
Model: "sequential_29"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
vgg16 (Functional)           (None, 7, 7, 512)         14714688
_________________________________________________________________
flatten_29 (Flatten)         (None, 25088)             0
_________________________________________________________________
dense_85 (Dense)             (None, 128)               3211392
_________________________________________________________________
dense_86 (Dense)             (None, 4)                 516
=================================================================
Total params: 17,926,596
Trainable params: 3,211,908
Non-trainable params: 14,714,688
_________________________________________________________________
```

[5 points] Train Model

In [125…

```
#FIT MODEL


STEP_SIZE_TRAIN=train_batches.n//train_batches.batch_size
STEP_SIZE_VALID=valid_batches.n//valid_batches.batch_size

NUM_EPOCHS = 500

res = model.fit(train_batches, epochs=NUM_EPOCHS, steps_per_epoch = STEP_SIZE_TRAIN, \
        validation_data=valid_batches, validation_steps= STEP_SIZE_VALID)
```

```
Epoch 1/500
21/21 [==============================] - 15s 694ms/step - loss: 1.4142 - categorical_acc
uracy: 0.2961 - val_loss: 1.3821 - val_categorical_accuracy: 0.2200
Epoch 2/500
21/21 [==============================] - 14s 647ms/step - loss: 1.3580 - categorical_acc
uracy: 0.3398 - val_loss: 1.3469 - val_categorical_accuracy: 0.3000
Epoch 3/500
21/21 [==============================] - 13s 641ms/step - loss: 1.2848 - categorical_acc
uracy: 0.4029 - val_loss: 1.2987 - val_categorical_accuracy: 0.5200
Epoch 4/500
21/21 [==============================] - 14s 643ms/step - loss: 1.2616 - categorical_acc
uracy: 0.4078 - val_loss: 1.2541 - val_categorical_accuracy: 0.4200
Epoch 5/500
21/21 [==============================] - 14s 642ms/step - loss: 1.2389 - categorical_acc
uracy: 0.4126 - val_loss: 1.2271 - val_categorical_accuracy: 0.4800
Epoch 6/500
21/21 [==============================] - 14s 643ms/step - loss: 1.1970 - categorical_acc
uracy: 0.5291 - val_loss: 1.1538 - val_categorical_accuracy: 0.5400
Epoch 7/500
21/21 [==============================] - 14s 643ms/step - loss: 1.1588 - categorical_acc
uracy: 0.5146 - val_loss: 1.1344 - val_categorical_accuracy: 0.5400
Epoch 8/500
21/21 [==============================] - 14s 642ms/step - loss: 1.1269 - categorical_acc
uracy: 0.5485 - val_loss: 1.1357 - val_categorical_accuracy: 0.4800
Epoch 9/500
21/21 [==============================] - 14s 662ms/step - loss: 1.1215 - categorical_acc
uracy: 0.5485 - val_loss: 1.0950 - val_categorical_accuracy: 0.5400
Epoch 10/500
21/21 [==============================] - 14s 651ms/step - loss: 1.0991 - categorical_acc
uracy: 0.5631 - val_loss: 1.0731 - val_categorical_accuracy: 0.6200
Epoch 11/500
21/21 [==============================] - 14s 650ms/step - loss: 1.0718 - categorical_acc
uracy: 0.5194 - val_loss: 1.0887 - val_categorical_accuracy: 0.5000
Epoch 12/500
21/21 [==============================] - 14s 652ms/step - loss: 1.0591 - categorical_acc
uracy: 0.5485 - val_loss: 1.0651 - val_categorical_accuracy: 0.4800
Epoch 13/500
21/21 [==============================] - 14s 654ms/step - loss: 1.0345 - categorical_acc
uracy: 0.6262 - val_loss: 1.0061 - val_categorical_accuracy: 0.7400
Epoch 14/500
21/21 [==============================] - 14s 652ms/step - loss: 1.0067 - categorical_acc
uracy: 0.5825 - val_loss: 1.0708 - val_categorical_accuracy: 0.4800
Epoch 15/500
21/21 [==============================] - 14s 648ms/step - loss: 1.0443 - categorical_acc
uracy: 0.5194 - val_loss: 0.9748 - val_categorical_accuracy: 0.6600
Epoch 16/500
21/21 [==============================] - 14s 657ms/step - loss: 0.9873 - categorical_acc
uracy: 0.6359 - val_loss: 0.9666 - val_categorical_accuracy: 0.6200
Epoch 17/500
```

```
21/21 [==============================] - 14s 651ms/step - loss: 0.9907 - categorical_acc
uracy: 0.6019 - val_loss: 0.9611 - val_categorical_accuracy: 0.6000
Epoch 18/500
21/21 [==============================] - 14s 653ms/step - loss: 0.9447 - categorical_acc
uracy: 0.6602 - val_loss: 0.9859 - val_categorical_accuracy: 0.5000
Epoch 19/500
21/21 [==============================] - 14s 655ms/step - loss: 0.9752 - categorical_acc
uracy: 0.5922 - val_loss: 0.9143 - val_categorical_accuracy: 0.6600
Epoch 20/500
21/21 [==============================] - 14s 659ms/step - loss: 0.9234 - categorical_acc
uracy: 0.6796 - val_loss: 0.9621 - val_categorical_accuracy: 0.5800
Epoch 21/500
21/21 [==============================] - 14s 653ms/step - loss: 0.9292 - categorical_acc
uracy: 0.6650 - val_loss: 0.9041 - val_categorical_accuracy: 0.6400
Epoch 22/500
21/21 [==============================] - 14s 657ms/step - loss: 0.8825 - categorical_acc
uracy: 0.7039 - val_loss: 0.8591 - val_categorical_accuracy: 0.5800
Epoch 23/500
21/21 [==============================] - 14s 655ms/step - loss: 0.9003 - categorical_acc
uracy: 0.6408 - val_loss: 0.9096 - val_categorical_accuracy: 0.6200
Epoch 24/500
21/21 [==============================] - 14s 671ms/step - loss: 0.8947 - categorical_acc
uracy: 0.6429 - val_loss: 0.8812 - val_categorical_accuracy: 0.6400
Epoch 25/500
21/21 [==============================] - 14s 656ms/step - loss: 0.8806 - categorical_acc
uracy: 0.6699 - val_loss: 0.9165 - val_categorical_accuracy: 0.6000
Epoch 26/500
21/21 [==============================] - 14s 656ms/step - loss: 0.8937 - categorical_acc
uracy: 0.6650 - val_loss: 0.8861 - val_categorical_accuracy: 0.5600
Epoch 27/500
21/21 [==============================] - 14s 656ms/step - loss: 0.8334 - categorical_acc
uracy: 0.6942 - val_loss: 0.8626 - val_categorical_accuracy: 0.6400
Epoch 28/500
21/21 [==============================] - 14s 656ms/step - loss: 0.8270 - categorical_acc
uracy: 0.7087 - val_loss: 0.8623 - val_categorical_accuracy: 0.6000
Epoch 29/500
21/21 [==============================] - 14s 662ms/step - loss: 0.8505 - categorical_acc
uracy: 0.6990 - val_loss: 0.8460 - val_categorical_accuracy: 0.6400
Epoch 30/500
21/21 [==============================] - 14s 654ms/step - loss: 0.8454 - categorical_acc
uracy: 0.6408 - val_loss: 0.9214 - val_categorical_accuracy: 0.6400
Epoch 31/500
21/21 [==============================] - 14s 656ms/step - loss: 0.8427 - categorical_acc
uracy: 0.6650 - val_loss: 0.9201 - val_categorical_accuracy: 0.6000
Epoch 32/500
21/21 [==============================] - 14s 663ms/step - loss: 0.8299 - categorical_acc
uracy: 0.6952 - val_loss: 0.8307 - val_categorical_accuracy: 0.6400
Epoch 33/500
21/21 [==============================] - 14s 656ms/step - loss: 0.8275 - categorical_acc
uracy: 0.6796 - val_loss: 0.8540 - val_categorical_accuracy: 0.6400
Epoch 34/500
21/21 [==============================] - 14s 660ms/step - loss: 0.8345 - categorical_acc
uracy: 0.6505 - val_loss: 0.9021 - val_categorical_accuracy: 0.5200
Epoch 35/500
21/21 [==============================] - 14s 652ms/step - loss: 0.7812 - categorical_acc
uracy: 0.6990 - val_loss: 0.8136 - val_categorical_accuracy: 0.6600
Epoch 36/500
21/21 [==============================] - 14s 654ms/step - loss: 0.8276 - categorical_acc
uracy: 0.6748 - val_loss: 0.8104 - val_categorical_accuracy: 0.6000
Epoch 37/500
```

```
21/21 [==============================] - 14s 654ms/step - loss: 0.8460 - categorical_acc
uracy: 0.6165 - val_loss: 0.8809 - val_categorical_accuracy: 0.6200
Epoch 38/500
21/21 [==============================] - 14s 662ms/step - loss: 0.8028 - categorical_acc
uracy: 0.6845 - val_loss: 0.7799 - val_categorical_accuracy: 0.6400
Epoch 39/500
21/21 [==============================] - 14s 653ms/step - loss: 0.7774 - categorical_acc
uracy: 0.6990 - val_loss: 0.7913 - val_categorical_accuracy: 0.6400
Epoch 40/500
21/21 [==============================] - 14s 652ms/step - loss: 0.7964 - categorical_acc
uracy: 0.6845 - val_loss: 0.7951 - val_categorical_accuracy: 0.6600
Epoch 41/500
21/21 [==============================] - 14s 659ms/step - loss: 0.7293 - categorical_acc
uracy: 0.7379 - val_loss: 0.7460 - val_categorical_accuracy: 0.6800
Epoch 42/500
21/21 [==============================] - 14s 662ms/step - loss: 0.7546 - categorical_acc
uracy: 0.7233 - val_loss: 0.7928 - val_categorical_accuracy: 0.7000
Epoch 43/500
21/21 [==============================] - 14s 665ms/step - loss: 0.7776 - categorical_acc
uracy: 0.6893 - val_loss: 0.8132 - val_categorical_accuracy: 0.6000
Epoch 44/500
21/21 [==============================] - 14s 655ms/step - loss: 0.7727 - categorical_acc
uracy: 0.6845 - val_loss: 0.8192 - val_categorical_accuracy: 0.6200
Epoch 45/500
21/21 [==============================] - 14s 652ms/step - loss: 0.7388 - categorical_acc
uracy: 0.7184 - val_loss: 0.7871 - val_categorical_accuracy: 0.6000
Epoch 46/500
21/21 [==============================] - 14s 657ms/step - loss: 0.7962 - categorical_acc
uracy: 0.6699 - val_loss: 0.7937 - val_categorical_accuracy: 0.6000
Epoch 47/500
21/21 [==============================] - 14s 653ms/step - loss: 0.7595 - categorical_acc
uracy: 0.6699 - val_loss: 0.7656 - val_categorical_accuracy: 0.6600
Epoch 48/500
21/21 [==============================] - 14s 654ms/step - loss: 0.7570 - categorical_acc
uracy: 0.6990 - val_loss: 0.8123 - val_categorical_accuracy: 0.6000
Epoch 49/500
21/21 [==============================] - 14s 656ms/step - loss: 0.7235 - categorical_acc
uracy: 0.6942 - val_loss: 0.8031 - val_categorical_accuracy: 0.6200
Epoch 50/500
21/21 [==============================] - 14s 663ms/step - loss: 0.7546 - categorical_acc
uracy: 0.7233 - val_loss: 0.7603 - val_categorical_accuracy: 0.6800
Epoch 51/500
21/21 [==============================] - 14s 663ms/step - loss: 0.7368 - categorical_acc
uracy: 0.7136 - val_loss: 0.7727 - val_categorical_accuracy: 0.6200
Epoch 52/500
21/21 [==============================] - 14s 653ms/step - loss: 0.7649 - categorical_acc
uracy: 0.6990 - val_loss: 0.8109 - val_categorical_accuracy: 0.6400
Epoch 53/500
21/21 [==============================] - 14s 653ms/step - loss: 0.7345 - categorical_acc
uracy: 0.7087 - val_loss: 0.7407 - val_categorical_accuracy: 0.6600
Epoch 54/500
21/21 [==============================] - 14s 657ms/step - loss: 0.7229 - categorical_acc
uracy: 0.7427 - val_loss: 0.7707 - val_categorical_accuracy: 0.6400
Epoch 55/500
21/21 [==============================] - 14s 663ms/step - loss: 0.7067 - categorical_acc
uracy: 0.7379 - val_loss: 0.7603 - val_categorical_accuracy: 0.6600
Epoch 56/500
21/21 [==============================] - 14s 655ms/step - loss: 0.7148 - categorical_acc
uracy: 0.7621 - val_loss: 0.7937 - val_categorical_accuracy: 0.6200
Epoch 57/500
```

```
21/21 [==============================] - 14s 650ms/step - loss: 0.7286 - categorical_acc
uracy: 0.6990 - val_loss: 0.7928 - val_categorical_accuracy: 0.6200
Epoch 58/500
21/21 [==============================] - 14s 655ms/step - loss: 0.7184 - categorical_acc
uracy: 0.7136 - val_loss: 0.7332 - val_categorical_accuracy: 0.6400
Epoch 59/500
21/21 [==============================] - 14s 655ms/step - loss: 0.7291 - categorical_acc
uracy: 0.7136 - val_loss: 0.7883 - val_categorical_accuracy: 0.6200
Epoch 60/500
21/21 [==============================] - 14s 656ms/step - loss: 0.7228 - categorical_acc
uracy: 0.7136 - val_loss: 0.7645 - val_categorical_accuracy: 0.5400
Epoch 61/500
21/21 [==============================] - 14s 659ms/step - loss: 0.6774 - categorical_acc
uracy: 0.7330 - val_loss: 0.6944 - val_categorical_accuracy: 0.7600
Epoch 62/500
21/21 [==============================] - 14s 654ms/step - loss: 0.7264 - categorical_acc
uracy: 0.7039 - val_loss: 0.6878 - val_categorical_accuracy: 0.7000
Epoch 63/500
21/21 [==============================] - 14s 655ms/step - loss: 0.7253 - categorical_acc
uracy: 0.6845 - val_loss: 0.7436 - val_categorical_accuracy: 0.6600
Epoch 64/500
21/21 [==============================] - 14s 656ms/step - loss: 0.7344 - categorical_acc
uracy: 0.6990 - val_loss: 0.7091 - val_categorical_accuracy: 0.6800
Epoch 65/500
21/21 [==============================] - 14s 667ms/step - loss: 0.7315 - categorical_acc
uracy: 0.7190 - val_loss: 0.7491 - val_categorical_accuracy: 0.6400
Epoch 66/500
21/21 [==============================] - 14s 654ms/step - loss: 0.6791 - categorical_acc
uracy: 0.7330 - val_loss: 0.7089 - val_categorical_accuracy: 0.6600
Epoch 67/500
21/21 [==============================] - 14s 656ms/step - loss: 0.7234 - categorical_acc
uracy: 0.6893 - val_loss: 0.7178 - val_categorical_accuracy: 0.7600
Epoch 68/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6670 - categorical_acc
uracy: 0.7330 - val_loss: 0.7202 - val_categorical_accuracy: 0.6800
Epoch 69/500
21/21 [==============================] - 14s 662ms/step - loss: 0.6665 - categorical_acc
uracy: 0.7524 - val_loss: 0.7328 - val_categorical_accuracy: 0.6800
Epoch 70/500
21/21 [==============================] - 14s 652ms/step - loss: 0.6485 - categorical_acc
uracy: 0.7621 - val_loss: 0.7090 - val_categorical_accuracy: 0.6800
Epoch 71/500
21/21 [==============================] - 14s 649ms/step - loss: 0.6895 - categorical_acc
uracy: 0.7039 - val_loss: 0.7922 - val_categorical_accuracy: 0.6200
Epoch 72/500
21/21 [==============================] - 14s 654ms/step - loss: 0.7097 - categorical_acc
uracy: 0.6699 - val_loss: 0.7654 - val_categorical_accuracy: 0.6800
Epoch 73/500
21/21 [==============================] - 14s 670ms/step - loss: 0.6543 - categorical_acc
uracy: 0.7476 - val_loss: 0.7910 - val_categorical_accuracy: 0.6200
Epoch 74/500
21/21 [==============================] - 14s 666ms/step - loss: 0.6765 - categorical_acc
uracy: 0.7670 - val_loss: 0.7384 - val_categorical_accuracy: 0.6600
Epoch 75/500
21/21 [==============================] - 14s 668ms/step - loss: 0.6890 - categorical_acc
uracy: 0.7524 - val_loss: 0.7511 - val_categorical_accuracy: 0.6400
Epoch 76/500
21/21 [==============================] - 14s 652ms/step - loss: 0.7002 - categorical_acc
uracy: 0.7039 - val_loss: 0.7950 - val_categorical_accuracy: 0.6600
Epoch 77/500
```

```
21/21 [==============================] - 14s 659ms/step - loss: 0.7083 - categorical_acc
uracy: 0.7330 - val_loss: 0.7377 - val_categorical_accuracy: 0.6800
Epoch 78/500
21/21 [==============================] - 14s 667ms/step - loss: 0.6738 - categorical_acc
uracy: 0.7621 - val_loss: 0.7289 - val_categorical_accuracy: 0.6400
Epoch 79/500
21/21 [==============================] - 14s 661ms/step - loss: 0.6749 - categorical_acc
uracy: 0.7379 - val_loss: 0.7194 - val_categorical_accuracy: 0.7200
Epoch 80/500
21/21 [==============================] - 14s 670ms/step - loss: 0.6732 - categorical_acc
uracy: 0.7621 - val_loss: 0.7827 - val_categorical_accuracy: 0.6000
Epoch 81/500
21/21 [==============================] - 14s 657ms/step - loss: 0.6605 - categorical_acc
uracy: 0.7330 - val_loss: 0.6818 - val_categorical_accuracy: 0.7000
Epoch 82/500
21/21 [==============================] - 14s 665ms/step - loss: 0.6446 - categorical_acc
uracy: 0.7427 - val_loss: 0.6890 - val_categorical_accuracy: 0.7400
Epoch 83/500
21/21 [==============================] - 14s 656ms/step - loss: 0.6541 - categorical_acc
uracy: 0.7670 - val_loss: 0.7012 - val_categorical_accuracy: 0.6800
Epoch 84/500
21/21 [==============================] - 14s 656ms/step - loss: 0.6619 - categorical_acc
uracy: 0.7379 - val_loss: 0.7140 - val_categorical_accuracy: 0.6400
Epoch 85/500
21/21 [==============================] - 14s 652ms/step - loss: 0.6830 - categorical_acc
uracy: 0.7476 - val_loss: 0.7522 - val_categorical_accuracy: 0.6200
Epoch 86/500
21/21 [==============================] - 14s 660ms/step - loss: 0.6419 - categorical_acc
uracy: 0.7427 - val_loss: 0.7710 - val_categorical_accuracy: 0.5200
Epoch 87/500
21/21 [==============================] - 14s 652ms/step - loss: 0.6996 - categorical_acc
uracy: 0.7427 - val_loss: 0.6979 - val_categorical_accuracy: 0.7000
Epoch 88/500
21/21 [==============================] - 14s 654ms/step - loss: 0.6542 - categorical_acc
uracy: 0.7330 - val_loss: 0.6852 - val_categorical_accuracy: 0.6600
Epoch 89/500
21/21 [==============================] - 14s 653ms/step - loss: 0.6346 - categorical_acc
uracy: 0.7476 - val_loss: 0.7164 - val_categorical_accuracy: 0.6200
Epoch 90/500
21/21 [==============================] - 14s 659ms/step - loss: 0.6649 - categorical_acc
uracy: 0.7330 - val_loss: 0.6902 - val_categorical_accuracy: 0.7000
Epoch 91/500
21/21 [==============================] - 14s 654ms/step - loss: 0.6092 - categorical_acc
uracy: 0.7913 - val_loss: 0.7757 - val_categorical_accuracy: 0.6000
Epoch 92/500
21/21 [==============================] - 14s 652ms/step - loss: 0.6453 - categorical_acc
uracy: 0.7621 - val_loss: 0.6256 - val_categorical_accuracy: 0.7000
Epoch 93/500
21/21 [==============================] - 14s 654ms/step - loss: 0.6158 - categorical_acc
uracy: 0.7670 - val_loss: 0.8152 - val_categorical_accuracy: 0.6200
Epoch 94/500
21/21 [==============================] - 14s 661ms/step - loss: 0.6506 - categorical_acc
uracy: 0.7379 - val_loss: 0.6905 - val_categorical_accuracy: 0.6800
Epoch 95/500
21/21 [==============================] - 14s 663ms/step - loss: 0.6553 - categorical_acc
uracy: 0.7619 - val_loss: 0.6883 - val_categorical_accuracy: 0.6800
Epoch 96/500
21/21 [==============================] - 14s 654ms/step - loss: 0.6471 - categorical_acc
uracy: 0.7282 - val_loss: 0.7228 - val_categorical_accuracy: 0.7000
Epoch 97/500
```

```
21/21 [==============================] - 14s 649ms/step - loss: 0.6481 - categorical_acc
uracy: 0.7476 - val_loss: 0.7072 - val_categorical_accuracy: 0.6600
Epoch 98/500
21/21 [==============================] - 14s 650ms/step - loss: 0.6418 - categorical_acc
uracy: 0.7767 - val_loss: 0.6805 - val_categorical_accuracy: 0.6600
Epoch 99/500
21/21 [==============================] - 14s 663ms/step - loss: 0.6507 - categorical_acc
uracy: 0.7330 - val_loss: 0.6660 - val_categorical_accuracy: 0.7200
Epoch 100/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6485 - categorical_acc
uracy: 0.7233 - val_loss: 0.7528 - val_categorical_accuracy: 0.6400
Epoch 101/500
21/21 [==============================] - 14s 648ms/step - loss: 0.6363 - categorical_acc
uracy: 0.7816 - val_loss: 0.7405 - val_categorical_accuracy: 0.6000
Epoch 102/500
21/21 [==============================] - 14s 656ms/step - loss: 0.6138 - categorical_acc
uracy: 0.7427 - val_loss: 0.6523 - val_categorical_accuracy: 0.6200
Epoch 103/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5949 - categorical_acc
uracy: 0.7864 - val_loss: 0.6699 - val_categorical_accuracy: 0.7200
Epoch 104/500
21/21 [==============================] - 14s 654ms/step - loss: 0.6433 - categorical_acc
uracy: 0.7816 - val_loss: 0.6656 - val_categorical_accuracy: 0.6800
Epoch 105/500
21/21 [==============================] - 14s 652ms/step - loss: 0.6125 - categorical_acc
uracy: 0.7282 - val_loss: 0.6369 - val_categorical_accuracy: 0.7000
Epoch 106/500
21/21 [==============================] - 14s 651ms/step - loss: 0.5947 - categorical_acc
uracy: 0.7961 - val_loss: 0.6747 - val_categorical_accuracy: 0.7000
Epoch 107/500
21/21 [==============================] - 14s 660ms/step - loss: 0.6216 - categorical_acc
uracy: 0.7379 - val_loss: 0.6994 - val_categorical_accuracy: 0.7000
Epoch 108/500
21/21 [==============================] - 14s 656ms/step - loss: 0.6399 - categorical_acc
uracy: 0.7379 - val_loss: 0.6638 - val_categorical_accuracy: 0.7600
Epoch 109/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5779 - categorical_acc
uracy: 0.8204 - val_loss: 0.6461 - val_categorical_accuracy: 0.7800
Epoch 110/500
21/21 [==============================] - 14s 662ms/step - loss: 0.6066 - categorical_acc
uracy: 0.7524 - val_loss: 0.7418 - val_categorical_accuracy: 0.6800
Epoch 111/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5882 - categorical_acc
uracy: 0.8010 - val_loss: 0.6703 - val_categorical_accuracy: 0.6600
Epoch 112/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6411 - categorical_acc
uracy: 0.7573 - val_loss: 0.7378 - val_categorical_accuracy: 0.6600
Epoch 113/500
21/21 [==============================] - 14s 652ms/step - loss: 0.6215 - categorical_acc
uracy: 0.7476 - val_loss: 0.7194 - val_categorical_accuracy: 0.6200
Epoch 114/500
21/21 [==============================] - 14s 654ms/step - loss: 0.6335 - categorical_acc
uracy: 0.7427 - val_loss: 0.6743 - val_categorical_accuracy: 0.7000
Epoch 115/500
21/21 [==============================] - 14s 658ms/step - loss: 0.6350 - categorical_acc
uracy: 0.7427 - val_loss: 0.6859 - val_categorical_accuracy: 0.7000
Epoch 116/500
21/21 [==============================] - 14s 652ms/step - loss: 0.6151 - categorical_acc
uracy: 0.7476 - val_loss: 0.6546 - val_categorical_accuracy: 0.7200
Epoch 117/500
```

```
21/21 [==============================] - 14s 660ms/step - loss: 0.6157 - categorical_acc
uracy: 0.7286 - val_loss: 0.7151 - val_categorical_accuracy: 0.7200
Epoch 118/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6570 - categorical_acc
uracy: 0.7427 - val_loss: 0.6916 - val_categorical_accuracy: 0.6600
Epoch 119/500
21/21 [==============================] - 14s 661ms/step - loss: 0.6019 - categorical_acc
uracy: 0.7476 - val_loss: 0.6935 - val_categorical_accuracy: 0.6800
Epoch 120/500
21/21 [==============================] - 14s 653ms/step - loss: 0.6227 - categorical_acc
uracy: 0.7379 - val_loss: 0.6806 - val_categorical_accuracy: 0.6600
Epoch 121/500
21/21 [==============================] - 14s 656ms/step - loss: 0.6531 - categorical_acc
uracy: 0.7282 - val_loss: 0.6946 - val_categorical_accuracy: 0.7200
Epoch 122/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5831 - categorical_acc
uracy: 0.7718 - val_loss: 0.6838 - val_categorical_accuracy: 0.7000
Epoch 123/500
21/21 [==============================] - 14s 651ms/step - loss: 0.6079 - categorical_acc
uracy: 0.7767 - val_loss: 0.7039 - val_categorical_accuracy: 0.6600
Epoch 124/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5949 - categorical_acc
uracy: 0.7864 - val_loss: 0.5464 - val_categorical_accuracy: 0.7200
Epoch 125/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6076 - categorical_acc
uracy: 0.7718 - val_loss: 0.7020 - val_categorical_accuracy: 0.6200
Epoch 126/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6194 - categorical_acc
uracy: 0.7767 - val_loss: 0.6127 - val_categorical_accuracy: 0.7200
Epoch 127/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5712 - categorical_acc
uracy: 0.7864 - val_loss: 0.7186 - val_categorical_accuracy: 0.6800
Epoch 128/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6624 - categorical_acc
uracy: 0.6942 - val_loss: 0.6821 - val_categorical_accuracy: 0.7200
Epoch 129/500
21/21 [==============================] - 14s 652ms/step - loss: 0.6160 - categorical_acc
uracy: 0.7427 - val_loss: 0.6464 - val_categorical_accuracy: 0.7000
Epoch 130/500
21/21 [==============================] - 14s 648ms/step - loss: 0.6333 - categorical_acc
uracy: 0.7379 - val_loss: 0.6983 - val_categorical_accuracy: 0.7000
Epoch 131/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5566 - categorical_acc
uracy: 0.7913 - val_loss: 0.6611 - val_categorical_accuracy: 0.7200
Epoch 132/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5958 - categorical_acc
uracy: 0.7524 - val_loss: 0.6338 - val_categorical_accuracy: 0.7200
Epoch 133/500
21/21 [==============================] - 14s 654ms/step - loss: 0.6173 - categorical_acc
uracy: 0.7621 - val_loss: 0.7271 - val_categorical_accuracy: 0.6600
Epoch 134/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5729 - categorical_acc
uracy: 0.7718 - val_loss: 0.8153 - val_categorical_accuracy: 0.5800
Epoch 135/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5944 - categorical_acc
uracy: 0.7718 - val_loss: 0.6326 - val_categorical_accuracy: 0.6800
Epoch 136/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5969 - categorical_acc
uracy: 0.7670 - val_loss: 0.7190 - val_categorical_accuracy: 0.6200
Epoch 137/500
```

```
21/21 [==============================] - 14s 655ms/step - loss: 0.6187 - categorical_acc
uracy: 0.7233 - val_loss: 0.6729 - val_categorical_accuracy: 0.6400
Epoch 138/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5940 - categorical_acc
uracy: 0.7864 - val_loss: 0.7383 - val_categorical_accuracy: 0.7000
Epoch 139/500
21/21 [==============================] - 14s 669ms/step - loss: 0.5905 - categorical_acc
uracy: 0.7427 - val_loss: 0.6269 - val_categorical_accuracy: 0.7600
Epoch 140/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6116 - categorical_acc
uracy: 0.7816 - val_loss: 0.6510 - val_categorical_accuracy: 0.7400
Epoch 141/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5905 - categorical_acc
uracy: 0.7670 - val_loss: 0.7577 - val_categorical_accuracy: 0.6600
Epoch 142/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5883 - categorical_acc
uracy: 0.7670 - val_loss: 0.7339 - val_categorical_accuracy: 0.6800
Epoch 143/500
21/21 [==============================] - 14s 658ms/step - loss: 0.6195 - categorical_acc
uracy: 0.7282 - val_loss: 0.6982 - val_categorical_accuracy: 0.6800
Epoch 144/500
21/21 [==============================] - 14s 655ms/step - loss: 0.6043 - categorical_acc
uracy: 0.7718 - val_loss: 0.6339 - val_categorical_accuracy: 0.6600
Epoch 145/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5516 - categorical_acc
uracy: 0.8301 - val_loss: 0.6749 - val_categorical_accuracy: 0.6800
Epoch 146/500
21/21 [==============================] - 14s 673ms/step - loss: 0.6239 - categorical_acc
uracy: 0.7282 - val_loss: 0.6150 - val_categorical_accuracy: 0.7400
Epoch 147/500
21/21 [==============================] - 14s 651ms/step - loss: 0.5487 - categorical_acc
uracy: 0.7961 - val_loss: 0.6319 - val_categorical_accuracy: 0.7400
Epoch 148/500
21/21 [==============================] - 14s 664ms/step - loss: 0.6007 - categorical_acc
uracy: 0.7767 - val_loss: 0.7328 - val_categorical_accuracy: 0.6400
Epoch 149/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5800 - categorical_acc
uracy: 0.7427 - val_loss: 0.7503 - val_categorical_accuracy: 0.5600
Epoch 150/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5695 - categorical_acc
uracy: 0.7864 - val_loss: 0.6920 - val_categorical_accuracy: 0.7200
Epoch 151/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5378 - categorical_acc
uracy: 0.8058 - val_loss: 0.7519 - val_categorical_accuracy: 0.6400
Epoch 152/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5663 - categorical_acc
uracy: 0.8204 - val_loss: 0.7105 - val_categorical_accuracy: 0.6600
Epoch 153/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5582 - categorical_acc
uracy: 0.7767 - val_loss: 0.6403 - val_categorical_accuracy: 0.7200
Epoch 154/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5221 - categorical_acc
uracy: 0.7670 - val_loss: 0.7253 - val_categorical_accuracy: 0.5800
Epoch 155/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5867 - categorical_acc
uracy: 0.7767 - val_loss: 0.6426 - val_categorical_accuracy: 0.7000
Epoch 156/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5850 - categorical_acc
uracy: 0.7573 - val_loss: 0.6474 - val_categorical_accuracy: 0.6400
Epoch 157/500
```

```
21/21 [==============================] - 14s 657ms/step - loss: 0.5498 - categorical_acc
uracy: 0.7816 - val_loss: 0.7152 - val_categorical_accuracy: 0.7000
Epoch 158/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5956 - categorical_acc
uracy: 0.7621 - val_loss: 0.5751 - val_categorical_accuracy: 0.7600
Epoch 159/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5548 - categorical_acc
uracy: 0.7621 - val_loss: 0.5522 - val_categorical_accuracy: 0.7800
Epoch 160/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5428 - categorical_acc
uracy: 0.8107 - val_loss: 0.6632 - val_categorical_accuracy: 0.7400
Epoch 161/500
21/21 [==============================] - 14s 662ms/step - loss: 0.5780 - categorical_acc
uracy: 0.7913 - val_loss: 0.7154 - val_categorical_accuracy: 0.7000
Epoch 162/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5811 - categorical_acc
uracy: 0.7476 - val_loss: 0.6978 - val_categorical_accuracy: 0.6400
Epoch 163/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5860 - categorical_acc
uracy: 0.7816 - val_loss: 0.6426 - val_categorical_accuracy: 0.6800
Epoch 164/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5739 - categorical_acc
uracy: 0.7524 - val_loss: 0.6600 - val_categorical_accuracy: 0.7000
Epoch 165/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5696 - categorical_acc
uracy: 0.7718 - val_loss: 0.6410 - val_categorical_accuracy: 0.7600
Epoch 166/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5308 - categorical_acc
uracy: 0.7524 - val_loss: 0.7462 - val_categorical_accuracy: 0.6400
Epoch 167/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5785 - categorical_acc
uracy: 0.7913 - val_loss: 0.7427 - val_categorical_accuracy: 0.6800
Epoch 168/500
21/21 [==============================] - 14s 667ms/step - loss: 0.5467 - categorical_acc
uracy: 0.7767 - val_loss: 0.6857 - val_categorical_accuracy: 0.7200
Epoch 169/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5564 - categorical_acc
uracy: 0.7816 - val_loss: 0.6365 - val_categorical_accuracy: 0.6800
Epoch 170/500
21/21 [==============================] - 14s 666ms/step - loss: 0.5699 - categorical_acc
uracy: 0.7864 - val_loss: 0.7030 - val_categorical_accuracy: 0.6800
Epoch 171/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5234 - categorical_acc
uracy: 0.8155 - val_loss: 0.6679 - val_categorical_accuracy: 0.6600
Epoch 172/500
21/21 [==============================] - 14s 663ms/step - loss: 0.5565 - categorical_acc
uracy: 0.7864 - val_loss: 0.7113 - val_categorical_accuracy: 0.6000
Epoch 173/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5872 - categorical_acc
uracy: 0.7816 - val_loss: 0.6886 - val_categorical_accuracy: 0.7200
Epoch 174/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5515 - categorical_acc
uracy: 0.7718 - val_loss: 0.6664 - val_categorical_accuracy: 0.7200
Epoch 175/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5140 - categorical_acc
uracy: 0.8010 - val_loss: 0.7428 - val_categorical_accuracy: 0.7400
Epoch 176/500
21/21 [==============================] - 14s 668ms/step - loss: 0.5526 - categorical_acc
uracy: 0.8058 - val_loss: 0.6113 - val_categorical_accuracy: 0.7200
Epoch 177/500
```

```
21/21 [==============================] - 14s 657ms/step - loss: 0.5532 - categorical_acc
uracy: 0.7621 - val_loss: 0.6056 - val_categorical_accuracy: 0.7200
Epoch 178/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5453 - categorical_acc
uracy: 0.7816 - val_loss: 0.7411 - val_categorical_accuracy: 0.6600
Epoch 179/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5738 - categorical_acc
uracy: 0.7767 - val_loss: 0.7093 - val_categorical_accuracy: 0.6400
Epoch 180/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5275 - categorical_acc
uracy: 0.7816 - val_loss: 0.7101 - val_categorical_accuracy: 0.6400
Epoch 181/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5784 - categorical_acc
uracy: 0.7718 - val_loss: 0.6531 - val_categorical_accuracy: 0.6600
Epoch 182/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5200 - categorical_acc
uracy: 0.7767 - val_loss: 0.7552 - val_categorical_accuracy: 0.6600
Epoch 183/500
21/21 [==============================] - 14s 667ms/step - loss: 0.5265 - categorical_acc
uracy: 0.8000 - val_loss: 0.6147 - val_categorical_accuracy: 0.6400
Epoch 184/500
21/21 [==============================] - 14s 663ms/step - loss: 0.5592 - categorical_acc
uracy: 0.7816 - val_loss: 0.6806 - val_categorical_accuracy: 0.6800
Epoch 185/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5594 - categorical_acc
uracy: 0.7621 - val_loss: 0.6649 - val_categorical_accuracy: 0.7400
Epoch 186/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5540 - categorical_acc
uracy: 0.7816 - val_loss: 0.6958 - val_categorical_accuracy: 0.6800
Epoch 187/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5354 - categorical_acc
uracy: 0.8058 - val_loss: 0.5609 - val_categorical_accuracy: 0.7400
Epoch 188/500
21/21 [==============================] - 14s 668ms/step - loss: 0.5397 - categorical_acc
uracy: 0.7864 - val_loss: 0.7479 - val_categorical_accuracy: 0.6800
Epoch 189/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5241 - categorical_acc
uracy: 0.8204 - val_loss: 0.5969 - val_categorical_accuracy: 0.7400
Epoch 190/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5944 - categorical_acc
uracy: 0.8010 - val_loss: 0.6383 - val_categorical_accuracy: 0.7800
Epoch 191/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5494 - categorical_acc
uracy: 0.7767 - val_loss: 0.6310 - val_categorical_accuracy: 0.7200
Epoch 192/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5548 - categorical_acc
uracy: 0.8058 - val_loss: 0.6838 - val_categorical_accuracy: 0.6600
Epoch 193/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5761 - categorical_acc
uracy: 0.7621 - val_loss: 0.7220 - val_categorical_accuracy: 0.6400
Epoch 194/500
21/21 [==============================] - 14s 667ms/step - loss: 0.5112 - categorical_acc
uracy: 0.8204 - val_loss: 0.7089 - val_categorical_accuracy: 0.7400
Epoch 195/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5674 - categorical_acc
uracy: 0.7864 - val_loss: 0.6131 - val_categorical_accuracy: 0.7000
Epoch 196/500
21/21 [==============================] - 14s 657ms/step - loss: 0.5370 - categorical_acc
uracy: 0.7476 - val_loss: 0.6436 - val_categorical_accuracy: 0.7200
Epoch 197/500
```

```
21/21 [==============================] - 14s 655ms/step - loss: 0.5572 - categorical_acc
uracy: 0.7913 - val_loss: 0.6058 - val_categorical_accuracy: 0.6800
Epoch 198/500
21/21 [==============================] - 14s 667ms/step - loss: 0.4922 - categorical_acc
uracy: 0.8058 - val_loss: 0.6343 - val_categorical_accuracy: 0.6800
Epoch 199/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5313 - categorical_acc
uracy: 0.7621 - val_loss: 0.6927 - val_categorical_accuracy: 0.7400
Epoch 200/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5254 - categorical_acc
uracy: 0.8204 - val_loss: 0.7500 - val_categorical_accuracy: 0.6400
Epoch 201/500
21/21 [==============================] - 14s 664ms/step - loss: 0.5301 - categorical_acc
uracy: 0.8010 - val_loss: 0.7077 - val_categorical_accuracy: 0.6400
Epoch 202/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5681 - categorical_acc
uracy: 0.8107 - val_loss: 0.5865 - val_categorical_accuracy: 0.7600
Epoch 203/500
21/21 [==============================] - 14s 651ms/step - loss: 0.5531 - categorical_acc
uracy: 0.7718 - val_loss: 0.6647 - val_categorical_accuracy: 0.6800
Epoch 204/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5130 - categorical_acc
uracy: 0.8058 - val_loss: 0.6556 - val_categorical_accuracy: 0.6600
Epoch 205/500
21/21 [==============================] - 14s 666ms/step - loss: 0.5419 - categorical_acc
uracy: 0.7913 - val_loss: 0.6152 - val_categorical_accuracy: 0.7400
Epoch 206/500
21/21 [==============================] - 14s 658ms/step - loss: 0.5452 - categorical_acc
uracy: 0.7573 - val_loss: 0.5776 - val_categorical_accuracy: 0.7000
Epoch 207/500
21/21 [==============================] - 14s 670ms/step - loss: 0.5757 - categorical_acc
uracy: 0.7905 - val_loss: 0.6833 - val_categorical_accuracy: 0.6400
Epoch 208/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5724 - categorical_acc
uracy: 0.7961 - val_loss: 0.6793 - val_categorical_accuracy: 0.7400
Epoch 209/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5603 - categorical_acc
uracy: 0.7718 - val_loss: 0.6374 - val_categorical_accuracy: 0.7200
Epoch 210/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5278 - categorical_acc
uracy: 0.7767 - val_loss: 0.6513 - val_categorical_accuracy: 0.6600
Epoch 211/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5411 - categorical_acc
uracy: 0.7718 - val_loss: 0.6194 - val_categorical_accuracy: 0.7200
Epoch 212/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5117 - categorical_acc
uracy: 0.7913 - val_loss: 0.6653 - val_categorical_accuracy: 0.6400
Epoch 213/500
21/21 [==============================] - 14s 666ms/step - loss: 0.5560 - categorical_acc
uracy: 0.7913 - val_loss: 0.7259 - val_categorical_accuracy: 0.6400
Epoch 214/500
21/21 [==============================] - 14s 663ms/step - loss: 0.5487 - categorical_acc
uracy: 0.7913 - val_loss: 0.6607 - val_categorical_accuracy: 0.6800
Epoch 215/500
21/21 [==============================] - 14s 664ms/step - loss: 0.5251 - categorical_acc
uracy: 0.8058 - val_loss: 0.7039 - val_categorical_accuracy: 0.7200
Epoch 216/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4927 - categorical_acc
uracy: 0.8252 - val_loss: 0.6685 - val_categorical_accuracy: 0.6800
Epoch 217/500
```

```
21/21 [==============================] - 14s 651ms/step - loss: 0.5768 - categorical_acc
uracy: 0.7670 - val_loss: 0.6666 - val_categorical_accuracy: 0.7200
Epoch 218/500
21/21 [==============================] - 14s 657ms/step - loss: 0.5144 - categorical_acc
uracy: 0.7913 - val_loss: 0.6870 - val_categorical_accuracy: 0.6200
Epoch 219/500
21/21 [==============================] - 14s 667ms/step - loss: 0.5283 - categorical_acc
uracy: 0.7816 - val_loss: 0.6686 - val_categorical_accuracy: 0.6800
Epoch 220/500
21/21 [==============================] - 14s 662ms/step - loss: 0.5402 - categorical_acc
uracy: 0.8107 - val_loss: 0.7399 - val_categorical_accuracy: 0.6400
Epoch 221/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5338 - categorical_acc
uracy: 0.7767 - val_loss: 0.6956 - val_categorical_accuracy: 0.6200
Epoch 222/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5723 - categorical_acc
uracy: 0.7670 - val_loss: 0.5932 - val_categorical_accuracy: 0.7200
Epoch 223/500
21/21 [==============================] - 14s 651ms/step - loss: 0.5466 - categorical_acc
uracy: 0.7913 - val_loss: 0.7676 - val_categorical_accuracy: 0.6600
Epoch 224/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5303 - categorical_acc
uracy: 0.7718 - val_loss: 0.6810 - val_categorical_accuracy: 0.7200
Epoch 225/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5273 - categorical_acc
uracy: 0.7864 - val_loss: 0.6906 - val_categorical_accuracy: 0.6800
Epoch 226/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4970 - categorical_acc
uracy: 0.8204 - val_loss: 0.7155 - val_categorical_accuracy: 0.6600
Epoch 227/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5228 - categorical_acc
uracy: 0.8350 - val_loss: 0.6732 - val_categorical_accuracy: 0.6400
Epoch 228/500
21/21 [==============================] - 14s 668ms/step - loss: 0.5421 - categorical_acc
uracy: 0.7864 - val_loss: 0.6643 - val_categorical_accuracy: 0.6400
Epoch 229/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5572 - categorical_acc
uracy: 0.7767 - val_loss: 0.6669 - val_categorical_accuracy: 0.6800
Epoch 230/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4791 - categorical_acc
uracy: 0.8301 - val_loss: 0.6519 - val_categorical_accuracy: 0.7000
Epoch 231/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5553 - categorical_acc
uracy: 0.8058 - val_loss: 0.5853 - val_categorical_accuracy: 0.6800
Epoch 232/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5494 - categorical_acc
uracy: 0.7816 - val_loss: 0.6421 - val_categorical_accuracy: 0.7400
Epoch 233/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5278 - categorical_acc
uracy: 0.8107 - val_loss: 0.6296 - val_categorical_accuracy: 0.7000
Epoch 234/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5084 - categorical_acc
uracy: 0.8155 - val_loss: 0.5566 - val_categorical_accuracy: 0.7800
Epoch 235/500
21/21 [==============================] - 14s 657ms/step - loss: 0.5192 - categorical_acc
uracy: 0.7864 - val_loss: 0.7274 - val_categorical_accuracy: 0.7200
Epoch 236/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5420 - categorical_acc
uracy: 0.7670 - val_loss: 0.7166 - val_categorical_accuracy: 0.6600
Epoch 237/500
```

```
21/21 [==============================] - 14s 656ms/step - loss: 0.5725 - categorical_acc
uracy: 0.7816 - val_loss: 0.5799 - val_categorical_accuracy: 0.7600
Epoch 238/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5465 - categorical_acc
uracy: 0.7913 - val_loss: 0.5992 - val_categorical_accuracy: 0.7200
Epoch 239/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5214 - categorical_acc
uracy: 0.7816 - val_loss: 0.6527 - val_categorical_accuracy: 0.6800
Epoch 240/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5239 - categorical_acc
uracy: 0.7767 - val_loss: 0.7102 - val_categorical_accuracy: 0.6600
Epoch 241/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4954 - categorical_acc
uracy: 0.8155 - val_loss: 0.6402 - val_categorical_accuracy: 0.6800
Epoch 242/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5785 - categorical_acc
uracy: 0.7913 - val_loss: 0.6338 - val_categorical_accuracy: 0.6800
Epoch 243/500
21/21 [==============================] - 14s 651ms/step - loss: 0.5340 - categorical_acc
uracy: 0.8155 - val_loss: 0.6196 - val_categorical_accuracy: 0.7000
Epoch 244/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5076 - categorical_acc
uracy: 0.8252 - val_loss: 0.6101 - val_categorical_accuracy: 0.6600
Epoch 245/500
21/21 [==============================] - 14s 662ms/step - loss: 0.5081 - categorical_acc
uracy: 0.8095 - val_loss: 0.7619 - val_categorical_accuracy: 0.6400
Epoch 246/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5036 - categorical_acc
uracy: 0.8155 - val_loss: 0.6658 - val_categorical_accuracy: 0.6600
Epoch 247/500
21/21 [==============================] - 14s 657ms/step - loss: 0.5228 - categorical_acc
uracy: 0.8010 - val_loss: 0.6548 - val_categorical_accuracy: 0.6800
Epoch 248/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5386 - categorical_acc
uracy: 0.7767 - val_loss: 0.6949 - val_categorical_accuracy: 0.6600
Epoch 249/500
21/21 [==============================] - 14s 665ms/step - loss: 0.5245 - categorical_acc
uracy: 0.8048 - val_loss: 0.6564 - val_categorical_accuracy: 0.7200
Epoch 250/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5205 - categorical_acc
uracy: 0.7670 - val_loss: 0.6543 - val_categorical_accuracy: 0.6600
Epoch 251/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5247 - categorical_acc
uracy: 0.8058 - val_loss: 0.6005 - val_categorical_accuracy: 0.7000
Epoch 252/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5002 - categorical_acc
uracy: 0.8107 - val_loss: 0.6071 - val_categorical_accuracy: 0.7400
Epoch 253/500
21/21 [==============================] - 14s 651ms/step - loss: 0.5517 - categorical_acc
uracy: 0.7621 - val_loss: 0.6627 - val_categorical_accuracy: 0.6600
Epoch 254/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5266 - categorical_acc
uracy: 0.7816 - val_loss: 0.7201 - val_categorical_accuracy: 0.6600
Epoch 255/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4958 - categorical_acc
uracy: 0.8107 - val_loss: 0.6810 - val_categorical_accuracy: 0.6200
Epoch 256/500
21/21 [==============================] - 14s 649ms/step - loss: 0.5081 - categorical_acc
uracy: 0.8204 - val_loss: 0.6815 - val_categorical_accuracy: 0.6600
Epoch 257/500
```

```
21/21 [==============================] - 14s 654ms/step - loss: 0.4953 - categorical_acc
uracy: 0.8058 - val_loss: 0.6437 - val_categorical_accuracy: 0.6800
Epoch 258/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5309 - categorical_acc
uracy: 0.8058 - val_loss: 0.7287 - val_categorical_accuracy: 0.6000
Epoch 259/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5213 - categorical_acc
uracy: 0.7767 - val_loss: 0.6999 - val_categorical_accuracy: 0.5800
Epoch 260/500
21/21 [==============================] - 14s 662ms/step - loss: 0.5509 - categorical_acc
uracy: 0.7816 - val_loss: 0.6622 - val_categorical_accuracy: 0.7200
Epoch 261/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5616 - categorical_acc
uracy: 0.7621 - val_loss: 0.5491 - val_categorical_accuracy: 0.7000
Epoch 262/500
21/21 [==============================] - 14s 664ms/step - loss: 0.4927 - categorical_acc
uracy: 0.8252 - val_loss: 0.6330 - val_categorical_accuracy: 0.7000
Epoch 263/500
21/21 [==============================] - 14s 664ms/step - loss: 0.5030 - categorical_acc
uracy: 0.8010 - val_loss: 0.7563 - val_categorical_accuracy: 0.6000
Epoch 264/500
21/21 [==============================] - 14s 650ms/step - loss: 0.5108 - categorical_acc
uracy: 0.8058 - val_loss: 0.6686 - val_categorical_accuracy: 0.6400
Epoch 265/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4884 - categorical_acc
uracy: 0.8107 - val_loss: 0.5992 - val_categorical_accuracy: 0.7200
Epoch 266/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4998 - categorical_acc
uracy: 0.7961 - val_loss: 0.5786 - val_categorical_accuracy: 0.6800
Epoch 267/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4785 - categorical_acc
uracy: 0.8058 - val_loss: 0.6344 - val_categorical_accuracy: 0.7200
Epoch 268/500
21/21 [==============================] - 14s 664ms/step - loss: 0.4841 - categorical_acc
uracy: 0.8333 - val_loss: 0.5789 - val_categorical_accuracy: 0.7000
Epoch 269/500
21/21 [==============================] - 14s 650ms/step - loss: 0.4862 - categorical_acc
uracy: 0.8058 - val_loss: 0.5819 - val_categorical_accuracy: 0.7200
Epoch 270/500
21/21 [==============================] - 14s 666ms/step - loss: 0.5145 - categorical_acc
uracy: 0.7718 - val_loss: 0.6629 - val_categorical_accuracy: 0.6600
Epoch 271/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5039 - categorical_acc
uracy: 0.7961 - val_loss: 0.6421 - val_categorical_accuracy: 0.7000
Epoch 272/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4749 - categorical_acc
uracy: 0.8252 - val_loss: 0.6905 - val_categorical_accuracy: 0.6600
Epoch 273/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4646 - categorical_acc
uracy: 0.8350 - val_loss: 0.7072 - val_categorical_accuracy: 0.6600
Epoch 274/500
21/21 [==============================] - 14s 663ms/step - loss: 0.4916 - categorical_acc
uracy: 0.7961 - val_loss: 0.7368 - val_categorical_accuracy: 0.6400
Epoch 275/500
21/21 [==============================] - 14s 663ms/step - loss: 0.5163 - categorical_acc
uracy: 0.7961 - val_loss: 0.6804 - val_categorical_accuracy: 0.6600
Epoch 276/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4685 - categorical_acc
uracy: 0.8155 - val_loss: 0.6917 - val_categorical_accuracy: 0.6200
Epoch 277/500
```

```
21/21 [==============================] - 14s 650ms/step - loss: 0.4731 - categorical_acc
uracy: 0.8010 - val_loss: 0.5501 - val_categorical_accuracy: 0.8000
Epoch 278/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4866 - categorical_acc
uracy: 0.7864 - val_loss: 0.6174 - val_categorical_accuracy: 0.7200
Epoch 279/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5174 - categorical_acc
uracy: 0.8058 - val_loss: 0.7890 - val_categorical_accuracy: 0.6400
Epoch 280/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4919 - categorical_acc
uracy: 0.7864 - val_loss: 0.7243 - val_categorical_accuracy: 0.6800
Epoch 281/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5235 - categorical_acc
uracy: 0.8204 - val_loss: 0.6337 - val_categorical_accuracy: 0.6800
Epoch 282/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4945 - categorical_acc
uracy: 0.8204 - val_loss: 0.7319 - val_categorical_accuracy: 0.6600
Epoch 283/500
21/21 [==============================] - 14s 660ms/step - loss: 0.5108 - categorical_acc
uracy: 0.8301 - val_loss: 0.6333 - val_categorical_accuracy: 0.7400
Epoch 284/500
21/21 [==============================] - 14s 661ms/step - loss: 0.5266 - categorical_acc
uracy: 0.8048 - val_loss: 0.7514 - val_categorical_accuracy: 0.6800
Epoch 285/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4986 - categorical_acc
uracy: 0.8107 - val_loss: 0.6579 - val_categorical_accuracy: 0.7400
Epoch 286/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4676 - categorical_acc
uracy: 0.8107 - val_loss: 0.6662 - val_categorical_accuracy: 0.6600
Epoch 287/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4632 - categorical_acc
uracy: 0.8204 - val_loss: 0.6551 - val_categorical_accuracy: 0.7200
Epoch 288/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4586 - categorical_acc
uracy: 0.8301 - val_loss: 0.6703 - val_categorical_accuracy: 0.6800
Epoch 289/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5461 - categorical_acc
uracy: 0.7816 - val_loss: 0.6878 - val_categorical_accuracy: 0.7200
Epoch 290/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5039 - categorical_acc
uracy: 0.8301 - val_loss: 0.5696 - val_categorical_accuracy: 0.7400
Epoch 291/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5283 - categorical_acc
uracy: 0.8155 - val_loss: 0.6663 - val_categorical_accuracy: 0.6400
Epoch 292/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4875 - categorical_acc
uracy: 0.7913 - val_loss: 0.6057 - val_categorical_accuracy: 0.7200
Epoch 293/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4966 - categorical_acc
uracy: 0.8204 - val_loss: 0.6093 - val_categorical_accuracy: 0.6400
Epoch 294/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4530 - categorical_acc
uracy: 0.8204 - val_loss: 0.6500 - val_categorical_accuracy: 0.6800
Epoch 295/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4901 - categorical_acc
uracy: 0.7961 - val_loss: 0.6964 - val_categorical_accuracy: 0.6000
Epoch 296/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5000 - categorical_acc
uracy: 0.8058 - val_loss: 0.6547 - val_categorical_accuracy: 0.6800
Epoch 297/500
```

```
21/21 [==============================] - 14s 652ms/step - loss: 0.4872 - categorical_acc
uracy: 0.8252 - val_loss: 0.6655 - val_categorical_accuracy: 0.7200
Epoch 298/500
21/21 [==============================] - 14s 664ms/step - loss: 0.4935 - categorical_acc
uracy: 0.8107 - val_loss: 0.6973 - val_categorical_accuracy: 0.6800
Epoch 299/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4693 - categorical_acc
uracy: 0.8592 - val_loss: 0.6049 - val_categorical_accuracy: 0.6400
Epoch 300/500
21/21 [==============================] - 14s 665ms/step - loss: 0.4897 - categorical_acc
uracy: 0.8238 - val_loss: 0.5941 - val_categorical_accuracy: 0.7800
Epoch 301/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5807 - categorical_acc
uracy: 0.7816 - val_loss: 0.7048 - val_categorical_accuracy: 0.7000
Epoch 302/500
21/21 [==============================] - 14s 657ms/step - loss: 0.5039 - categorical_acc
uracy: 0.8155 - val_loss: 0.7153 - val_categorical_accuracy: 0.6000
Epoch 303/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5020 - categorical_acc
uracy: 0.8058 - val_loss: 0.7078 - val_categorical_accuracy: 0.6400
Epoch 304/500
21/21 [==============================] - 14s 662ms/step - loss: 0.4975 - categorical_acc
uracy: 0.7961 - val_loss: 0.6536 - val_categorical_accuracy: 0.7600
Epoch 305/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4632 - categorical_acc
uracy: 0.8204 - val_loss: 0.6584 - val_categorical_accuracy: 0.6400
Epoch 306/500
21/21 [==============================] - 14s 657ms/step - loss: 0.5138 - categorical_acc
uracy: 0.8058 - val_loss: 0.5631 - val_categorical_accuracy: 0.8000
Epoch 307/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4963 - categorical_acc
uracy: 0.7961 - val_loss: 0.6824 - val_categorical_accuracy: 0.6200
Epoch 308/500
21/21 [==============================] - 14s 650ms/step - loss: 0.4706 - categorical_acc
uracy: 0.8398 - val_loss: 0.6174 - val_categorical_accuracy: 0.7000
Epoch 309/500
21/21 [==============================] - 14s 655ms/step - loss: 0.5411 - categorical_acc
uracy: 0.7961 - val_loss: 0.6556 - val_categorical_accuracy: 0.7000
Epoch 310/500
21/21 [==============================] - 14s 653ms/step - loss: 0.5030 - categorical_acc
uracy: 0.7864 - val_loss: 0.6409 - val_categorical_accuracy: 0.6600
Epoch 311/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4690 - categorical_acc
uracy: 0.8447 - val_loss: 0.5998 - val_categorical_accuracy: 0.7400
Epoch 312/500
21/21 [==============================] - 14s 662ms/step - loss: 0.4722 - categorical_acc
uracy: 0.8058 - val_loss: 0.6100 - val_categorical_accuracy: 0.7200
Epoch 313/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4777 - categorical_acc
uracy: 0.8107 - val_loss: 0.6194 - val_categorical_accuracy: 0.7400
Epoch 314/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4308 - categorical_acc
uracy: 0.8398 - val_loss: 0.6364 - val_categorical_accuracy: 0.7000
Epoch 315/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4970 - categorical_acc
uracy: 0.8155 - val_loss: 0.6138 - val_categorical_accuracy: 0.6800
Epoch 316/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4771 - categorical_acc
uracy: 0.8350 - val_loss: 0.6121 - val_categorical_accuracy: 0.7200
Epoch 317/500
```

```
21/21 [==============================] - 14s 654ms/step - loss: 0.4924 - categorical_acc
uracy: 0.8204 - val_loss: 0.7032 - val_categorical_accuracy: 0.6600
Epoch 318/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4472 - categorical_acc
uracy: 0.8155 - val_loss: 0.6822 - val_categorical_accuracy: 0.6600
Epoch 319/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4910 - categorical_acc
uracy: 0.8155 - val_loss: 0.8182 - val_categorical_accuracy: 0.6400
Epoch 320/500
21/21 [==============================] - 14s 667ms/step - loss: 0.4671 - categorical_acc
uracy: 0.8544 - val_loss: 0.7251 - val_categorical_accuracy: 0.6400
Epoch 321/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4648 - categorical_acc
uracy: 0.8350 - val_loss: 0.6988 - val_categorical_accuracy: 0.7000
Epoch 322/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4677 - categorical_acc
uracy: 0.7961 - val_loss: 0.8105 - val_categorical_accuracy: 0.6600
Epoch 323/500
21/21 [==============================] - 14s 651ms/step - loss: 0.5024 - categorical_acc
uracy: 0.7816 - val_loss: 0.6308 - val_categorical_accuracy: 0.7200
Epoch 324/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4552 - categorical_acc
uracy: 0.8301 - val_loss: 0.4931 - val_categorical_accuracy: 0.7800
Epoch 325/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4965 - categorical_acc
uracy: 0.7767 - val_loss: 0.5362 - val_categorical_accuracy: 0.7800
Epoch 326/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4996 - categorical_acc
uracy: 0.8010 - val_loss: 0.6861 - val_categorical_accuracy: 0.6400
Epoch 327/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4611 - categorical_acc
uracy: 0.8107 - val_loss: 0.6720 - val_categorical_accuracy: 0.6600
Epoch 328/500
21/21 [==============================] - 14s 670ms/step - loss: 0.4734 - categorical_acc
uracy: 0.8204 - val_loss: 0.6219 - val_categorical_accuracy: 0.7200
Epoch 329/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4822 - categorical_acc
uracy: 0.8058 - val_loss: 0.6314 - val_categorical_accuracy: 0.6800
Epoch 330/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4336 - categorical_acc
uracy: 0.8204 - val_loss: 0.6737 - val_categorical_accuracy: 0.7200
Epoch 331/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4897 - categorical_acc
uracy: 0.7670 - val_loss: 0.5700 - val_categorical_accuracy: 0.7800
Epoch 332/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4917 - categorical_acc
uracy: 0.7961 - val_loss: 0.6157 - val_categorical_accuracy: 0.7200
Epoch 333/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4393 - categorical_acc
uracy: 0.8495 - val_loss: 0.7174 - val_categorical_accuracy: 0.5800
Epoch 334/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4949 - categorical_acc
uracy: 0.7670 - val_loss: 0.7013 - val_categorical_accuracy: 0.6600
Epoch 335/500
21/21 [==============================] - 14s 669ms/step - loss: 0.4521 - categorical_acc
uracy: 0.8398 - val_loss: 0.5837 - val_categorical_accuracy: 0.7600
Epoch 336/500
21/21 [==============================] - 14s 671ms/step - loss: 0.4929 - categorical_acc
uracy: 0.8010 - val_loss: 0.6561 - val_categorical_accuracy: 0.7200
Epoch 337/500
```

```
21/21 [==============================] - 14s 666ms/step - loss: 0.5206 - categorical_acc
uracy: 0.7762 - val_loss: 0.6865 - val_categorical_accuracy: 0.7200
Epoch 338/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4429 - categorical_acc
uracy: 0.8689 - val_loss: 0.5472 - val_categorical_accuracy: 0.7200
Epoch 339/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5013 - categorical_acc
uracy: 0.7816 - val_loss: 0.6250 - val_categorical_accuracy: 0.6600
Epoch 340/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4698 - categorical_acc
uracy: 0.8010 - val_loss: 0.6550 - val_categorical_accuracy: 0.6600
Epoch 341/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5016 - categorical_acc
uracy: 0.7864 - val_loss: 0.6339 - val_categorical_accuracy: 0.7800
Epoch 342/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4721 - categorical_acc
uracy: 0.8301 - val_loss: 0.6384 - val_categorical_accuracy: 0.6400
Epoch 343/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4977 - categorical_acc
uracy: 0.8252 - val_loss: 0.6400 - val_categorical_accuracy: 0.7000
Epoch 344/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4762 - categorical_acc
uracy: 0.8010 - val_loss: 0.5456 - val_categorical_accuracy: 0.7200
Epoch 345/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4886 - categorical_acc
uracy: 0.8107 - val_loss: 0.6040 - val_categorical_accuracy: 0.7200
Epoch 346/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5000 - categorical_acc
uracy: 0.8155 - val_loss: 0.5854 - val_categorical_accuracy: 0.7200
Epoch 347/500
21/21 [==============================] - 14s 667ms/step - loss: 0.4769 - categorical_acc
uracy: 0.8155 - val_loss: 0.7586 - val_categorical_accuracy: 0.7000
Epoch 348/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4605 - categorical_acc
uracy: 0.8155 - val_loss: 0.6990 - val_categorical_accuracy: 0.6400
Epoch 349/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4770 - categorical_acc
uracy: 0.8155 - val_loss: 0.6990 - val_categorical_accuracy: 0.7000
Epoch 350/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4821 - categorical_acc
uracy: 0.8301 - val_loss: 0.6735 - val_categorical_accuracy: 0.6800
Epoch 351/500
21/21 [==============================] - 14s 664ms/step - loss: 0.4918 - categorical_acc
uracy: 0.8252 - val_loss: 0.7496 - val_categorical_accuracy: 0.6400
Epoch 352/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4834 - categorical_acc
uracy: 0.7961 - val_loss: 0.7007 - val_categorical_accuracy: 0.6400
Epoch 353/500
21/21 [==============================] - 14s 652ms/step - loss: 0.5183 - categorical_acc
uracy: 0.7961 - val_loss: 0.6018 - val_categorical_accuracy: 0.7800
Epoch 354/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4653 - categorical_acc
uracy: 0.8252 - val_loss: 0.7391 - val_categorical_accuracy: 0.6400
Epoch 355/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4796 - categorical_acc
uracy: 0.8058 - val_loss: 0.5911 - val_categorical_accuracy: 0.7000
Epoch 356/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4827 - categorical_acc
uracy: 0.8350 - val_loss: 0.6952 - val_categorical_accuracy: 0.6800
Epoch 357/500
```

```
21/21 [==============================] - 14s 653ms/step - loss: 0.4693 - categorical_acc
uracy: 0.8204 - val_loss: 0.6151 - val_categorical_accuracy: 0.6600
Epoch 358/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4976 - categorical_acc
uracy: 0.8301 - val_loss: 0.6386 - val_categorical_accuracy: 0.6800
Epoch 359/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4604 - categorical_acc
uracy: 0.8301 - val_loss: 0.5848 - val_categorical_accuracy: 0.7800
Epoch 360/500
21/21 [==============================] - 14s 650ms/step - loss: 0.4633 - categorical_acc
uracy: 0.8058 - val_loss: 0.6743 - val_categorical_accuracy: 0.6800
Epoch 361/500
21/21 [==============================] - 14s 668ms/step - loss: 0.4828 - categorical_acc
uracy: 0.8204 - val_loss: 0.6475 - val_categorical_accuracy: 0.7400
Epoch 362/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4905 - categorical_acc
uracy: 0.8155 - val_loss: 0.5579 - val_categorical_accuracy: 0.7200
Epoch 363/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4545 - categorical_acc
uracy: 0.8398 - val_loss: 0.7069 - val_categorical_accuracy: 0.6000
Epoch 364/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4973 - categorical_acc
uracy: 0.7864 - val_loss: 0.6783 - val_categorical_accuracy: 0.7000
Epoch 365/500
21/21 [==============================] - 14s 654ms/step - loss: 0.5059 - categorical_acc
uracy: 0.8252 - val_loss: 0.7408 - val_categorical_accuracy: 0.6000
Epoch 366/500
21/21 [==============================] - 14s 653ms/step - loss: 0.4532 - categorical_acc
uracy: 0.8447 - val_loss: 0.8126 - val_categorical_accuracy: 0.7000
Epoch 367/500
21/21 [==============================] - 14s 665ms/step - loss: 0.4693 - categorical_acc
uracy: 0.8301 - val_loss: 0.6383 - val_categorical_accuracy: 0.6800
Epoch 368/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4285 - categorical_acc
uracy: 0.8495 - val_loss: 0.7046 - val_categorical_accuracy: 0.7600
Epoch 369/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4494 - categorical_acc
uracy: 0.8495 - val_loss: 0.6310 - val_categorical_accuracy: 0.7200
Epoch 370/500
21/21 [==============================] - 14s 668ms/step - loss: 0.4537 - categorical_acc
uracy: 0.8495 - val_loss: 0.6672 - val_categorical_accuracy: 0.6800
Epoch 371/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4613 - categorical_acc
uracy: 0.7961 - val_loss: 0.5753 - val_categorical_accuracy: 0.7400
Epoch 372/500
21/21 [==============================] - 14s 661ms/step - loss: 0.4612 - categorical_acc
uracy: 0.8495 - val_loss: 0.6524 - val_categorical_accuracy: 0.7400
Epoch 373/500
21/21 [==============================] - 14s 667ms/step - loss: 0.4814 - categorical_acc
uracy: 0.8010 - val_loss: 0.6069 - val_categorical_accuracy: 0.7200
Epoch 374/500
21/21 [==============================] - 14s 651ms/step - loss: 0.4652 - categorical_acc
uracy: 0.8155 - val_loss: 0.6828 - val_categorical_accuracy: 0.6800
Epoch 375/500
21/21 [==============================] - 14s 669ms/step - loss: 0.4574 - categorical_acc
uracy: 0.8252 - val_loss: 0.6710 - val_categorical_accuracy: 0.6800
Epoch 376/500
21/21 [==============================] - 14s 664ms/step - loss: 0.4647 - categorical_acc
uracy: 0.7961 - val_loss: 0.5922 - val_categorical_accuracy: 0.7400
Epoch 377/500
```

```
21/21 [==============================] - 14s 665ms/step - loss: 0.4300 - categorical_acc
uracy: 0.8447 - val_loss: 0.6358 - val_categorical_accuracy: 0.6800
Epoch 378/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4695 - categorical_acc
uracy: 0.8252 - val_loss: 0.7140 - val_categorical_accuracy: 0.6600
Epoch 379/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4322 - categorical_acc
uracy: 0.8350 - val_loss: 0.5330 - val_categorical_accuracy: 0.7800
Epoch 380/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4997 - categorical_acc
uracy: 0.7718 - val_loss: 0.6027 - val_categorical_accuracy: 0.6400
Epoch 381/500
21/21 [==============================] - 14s 651ms/step - loss: 0.4645 - categorical_acc
uracy: 0.7961 - val_loss: 0.6476 - val_categorical_accuracy: 0.6800
Epoch 382/500
21/21 [==============================] - 14s 664ms/step - loss: 0.4932 - categorical_acc
uracy: 0.8190 - val_loss: 0.7255 - val_categorical_accuracy: 0.6800
Epoch 383/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4953 - categorical_acc
uracy: 0.8301 - val_loss: 0.6368 - val_categorical_accuracy: 0.6800
Epoch 384/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4593 - categorical_acc
uracy: 0.8252 - val_loss: 0.5372 - val_categorical_accuracy: 0.7600
Epoch 385/500
21/21 [==============================] - 14s 665ms/step - loss: 0.4283 - categorical_acc
uracy: 0.8333 - val_loss: 0.6953 - val_categorical_accuracy: 0.6800
Epoch 386/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4661 - categorical_acc
uracy: 0.8495 - val_loss: 0.5890 - val_categorical_accuracy: 0.7800
Epoch 387/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4999 - categorical_acc
uracy: 0.8204 - val_loss: 0.6029 - val_categorical_accuracy: 0.7000
Epoch 388/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4637 - categorical_acc
uracy: 0.8398 - val_loss: 0.8315 - val_categorical_accuracy: 0.6600
Epoch 389/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4311 - categorical_acc
uracy: 0.8204 - val_loss: 0.6658 - val_categorical_accuracy: 0.7000
Epoch 390/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4736 - categorical_acc
uracy: 0.8350 - val_loss: 0.6861 - val_categorical_accuracy: 0.6800
Epoch 391/500
21/21 [==============================] - 14s 651ms/step - loss: 0.4722 - categorical_acc
uracy: 0.8204 - val_loss: 0.5046 - val_categorical_accuracy: 0.8000
Epoch 392/500
21/21 [==============================] - 14s 664ms/step - loss: 0.4859 - categorical_acc
uracy: 0.8107 - val_loss: 0.7161 - val_categorical_accuracy: 0.6200
Epoch 393/500
21/21 [==============================] - 14s 656ms/step - loss: 0.5159 - categorical_acc
uracy: 0.7864 - val_loss: 0.6450 - val_categorical_accuracy: 0.7000
Epoch 394/500
21/21 [==============================] - 14s 671ms/step - loss: 0.5028 - categorical_acc
uracy: 0.8204 - val_loss: 0.7090 - val_categorical_accuracy: 0.6600
Epoch 395/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4858 - categorical_acc
uracy: 0.8107 - val_loss: 0.6905 - val_categorical_accuracy: 0.7000
Epoch 396/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4387 - categorical_acc
uracy: 0.8641 - val_loss: 0.7451 - val_categorical_accuracy: 0.6600
Epoch 397/500
```

```
21/21 [==============================] - 14s 656ms/step - loss: 0.4701 - categorical_acc
uracy: 0.8058 - val_loss: 0.6899 - val_categorical_accuracy: 0.7400
Epoch 398/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4779 - categorical_acc
uracy: 0.8252 - val_loss: 0.6134 - val_categorical_accuracy: 0.7400
Epoch 399/500
21/21 [==============================] - 14s 665ms/step - loss: 0.4495 - categorical_acc
uracy: 0.8204 - val_loss: 0.6759 - val_categorical_accuracy: 0.7000
Epoch 400/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4414 - categorical_acc
uracy: 0.8544 - val_loss: 0.6700 - val_categorical_accuracy: 0.6600
Epoch 401/500
21/21 [==============================] - 14s 680ms/step - loss: 0.4402 - categorical_acc
uracy: 0.8350 - val_loss: 0.6249 - val_categorical_accuracy: 0.6800
Epoch 402/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4132 - categorical_acc
uracy: 0.8447 - val_loss: 0.5967 - val_categorical_accuracy: 0.7600
Epoch 403/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4713 - categorical_acc
uracy: 0.8107 - val_loss: 0.5873 - val_categorical_accuracy: 0.7200
Epoch 404/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4942 - categorical_acc
uracy: 0.8155 - val_loss: 0.5678 - val_categorical_accuracy: 0.7200
Epoch 405/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4262 - categorical_acc
uracy: 0.8495 - val_loss: 0.5853 - val_categorical_accuracy: 0.7800
Epoch 406/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4439 - categorical_acc
uracy: 0.8204 - val_loss: 0.6781 - val_categorical_accuracy: 0.6600
Epoch 407/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4699 - categorical_acc
uracy: 0.8058 - val_loss: 0.7146 - val_categorical_accuracy: 0.6000
Epoch 408/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4274 - categorical_acc
uracy: 0.8107 - val_loss: 0.6188 - val_categorical_accuracy: 0.7800
Epoch 409/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4622 - categorical_acc
uracy: 0.8447 - val_loss: 0.6158 - val_categorical_accuracy: 0.7400
Epoch 410/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4437 - categorical_acc
uracy: 0.8495 - val_loss: 0.5688 - val_categorical_accuracy: 0.7600
Epoch 411/500
21/21 [==============================] - 14s 652ms/step - loss: 0.4767 - categorical_acc
uracy: 0.8155 - val_loss: 0.6952 - val_categorical_accuracy: 0.7200
Epoch 412/500
21/21 [==============================] - 14s 651ms/step - loss: 0.4441 - categorical_acc
uracy: 0.8398 - val_loss: 0.6529 - val_categorical_accuracy: 0.7000
Epoch 413/500
21/21 [==============================] - 14s 677ms/step - loss: 0.4820 - categorical_acc
uracy: 0.8333 - val_loss: 0.5158 - val_categorical_accuracy: 0.7200
Epoch 414/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4570 - categorical_acc
uracy: 0.8155 - val_loss: 0.6059 - val_categorical_accuracy: 0.7200
Epoch 415/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4303 - categorical_acc
uracy: 0.8350 - val_loss: 0.6844 - val_categorical_accuracy: 0.7000
Epoch 416/500
21/21 [==============================] - 14s 665ms/step - loss: 0.4421 - categorical_acc
uracy: 0.8252 - val_loss: 0.7333 - val_categorical_accuracy: 0.6800
Epoch 417/500
```

```
21/21 [==============================] - 14s 654ms/step - loss: 0.5232 - categorical_acc
uracy: 0.8155 - val_loss: 0.7434 - val_categorical_accuracy: 0.6200
Epoch 418/500
21/21 [==============================] - 14s 670ms/step - loss: 0.4855 - categorical_acc
uracy: 0.8058 - val_loss: 0.5129 - val_categorical_accuracy: 0.8000
Epoch 419/500
21/21 [==============================] - 14s 669ms/step - loss: 0.4640 - categorical_acc
uracy: 0.8238 - val_loss: 0.5660 - val_categorical_accuracy: 0.7400
Epoch 420/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4587 - categorical_acc
uracy: 0.8398 - val_loss: 0.7318 - val_categorical_accuracy: 0.6600
Epoch 421/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4315 - categorical_acc
uracy: 0.8204 - val_loss: 0.6954 - val_categorical_accuracy: 0.7400
Epoch 422/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4376 - categorical_acc
uracy: 0.8252 - val_loss: 0.7025 - val_categorical_accuracy: 0.6200
Epoch 423/500
21/21 [==============================] - 14s 662ms/step - loss: 0.4441 - categorical_acc
uracy: 0.8204 - val_loss: 0.6817 - val_categorical_accuracy: 0.6800
Epoch 424/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4151 - categorical_acc
uracy: 0.8738 - val_loss: 0.6261 - val_categorical_accuracy: 0.7000
Epoch 425/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4641 - categorical_acc
uracy: 0.8301 - val_loss: 0.7493 - val_categorical_accuracy: 0.6800
Epoch 426/500
21/21 [==============================] - 14s 675ms/step - loss: 0.4575 - categorical_acc
uracy: 0.8350 - val_loss: 0.5859 - val_categorical_accuracy: 0.7400
Epoch 427/500
21/21 [==============================] - 14s 661ms/step - loss: 0.4708 - categorical_acc
uracy: 0.8058 - val_loss: 0.5629 - val_categorical_accuracy: 0.7200
Epoch 428/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4457 - categorical_acc
uracy: 0.8155 - val_loss: 0.5969 - val_categorical_accuracy: 0.7400
Epoch 429/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4406 - categorical_acc
uracy: 0.8495 - val_loss: 0.5839 - val_categorical_accuracy: 0.7800
Epoch 430/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4419 - categorical_acc
uracy: 0.8350 - val_loss: 0.6880 - val_categorical_accuracy: 0.7000
Epoch 431/500
21/21 [==============================] - 14s 668ms/step - loss: 0.4332 - categorical_acc
uracy: 0.8544 - val_loss: 0.7100 - val_categorical_accuracy: 0.7000
Epoch 432/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4635 - categorical_acc
uracy: 0.8155 - val_loss: 0.7050 - val_categorical_accuracy: 0.6800
Epoch 433/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4459 - categorical_acc
uracy: 0.8252 - val_loss: 0.7191 - val_categorical_accuracy: 0.6800
Epoch 434/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4337 - categorical_acc
uracy: 0.8204 - val_loss: 0.6177 - val_categorical_accuracy: 0.7200
Epoch 435/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4366 - categorical_acc
uracy: 0.8058 - val_loss: 0.6694 - val_categorical_accuracy: 0.7000
Epoch 436/500
21/21 [==============================] - 14s 661ms/step - loss: 0.4196 - categorical_acc
uracy: 0.8544 - val_loss: 0.6664 - val_categorical_accuracy: 0.7200
Epoch 437/500
```

```
21/21 [==============================] - 14s 660ms/step - loss: 0.4490 - categorical_acc
uracy: 0.8204 - val_loss: 0.5099 - val_categorical_accuracy: 0.7600
Epoch 438/500
21/21 [==============================] - 14s 662ms/step - loss: 0.4459 - categorical_acc
uracy: 0.8447 - val_loss: 0.6506 - val_categorical_accuracy: 0.7000
Epoch 439/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4440 - categorical_acc
uracy: 0.8155 - val_loss: 0.5537 - val_categorical_accuracy: 0.7200
Epoch 440/500
21/21 [==============================] - 14s 675ms/step - loss: 0.4372 - categorical_acc
uracy: 0.8155 - val_loss: 0.6082 - val_categorical_accuracy: 0.7200
Epoch 441/500
21/21 [==============================] - 14s 661ms/step - loss: 0.4228 - categorical_acc
uracy: 0.8398 - val_loss: 0.5801 - val_categorical_accuracy: 0.8000
Epoch 442/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4646 - categorical_acc
uracy: 0.8155 - val_loss: 0.6662 - val_categorical_accuracy: 0.6600
Epoch 443/500
21/21 [==============================] - 14s 654ms/step - loss: 0.4387 - categorical_acc
uracy: 0.8398 - val_loss: 0.7844 - val_categorical_accuracy: 0.6600
Epoch 444/500
21/21 [==============================] - 14s 663ms/step - loss: 0.4362 - categorical_acc
uracy: 0.8252 - val_loss: 0.5982 - val_categorical_accuracy: 0.7600
Epoch 445/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4829 - categorical_acc
uracy: 0.8107 - val_loss: 0.7075 - val_categorical_accuracy: 0.6600
Epoch 446/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4807 - categorical_acc
uracy: 0.8107 - val_loss: 0.5402 - val_categorical_accuracy: 0.7800
Epoch 447/500
21/21 [==============================] - 14s 659ms/step - loss: 0.5079 - categorical_acc
uracy: 0.7961 - val_loss: 0.6846 - val_categorical_accuracy: 0.7000
Epoch 448/500
21/21 [==============================] - 14s 657ms/step - loss: 0.3957 - categorical_acc
uracy: 0.8447 - val_loss: 0.6282 - val_categorical_accuracy: 0.7200
Epoch 449/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4628 - categorical_acc
uracy: 0.8398 - val_loss: 0.6233 - val_categorical_accuracy: 0.6600
Epoch 450/500
21/21 [==============================] - 14s 662ms/step - loss: 0.4702 - categorical_acc
uracy: 0.8398 - val_loss: 0.6921 - val_categorical_accuracy: 0.6800
Epoch 451/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4282 - categorical_acc
uracy: 0.8495 - val_loss: 0.7043 - val_categorical_accuracy: 0.6600
Epoch 452/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4404 - categorical_acc
uracy: 0.8155 - val_loss: 0.5662 - val_categorical_accuracy: 0.6600
Epoch 453/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4494 - categorical_acc
uracy: 0.8155 - val_loss: 0.6938 - val_categorical_accuracy: 0.7200
Epoch 454/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4721 - categorical_acc
uracy: 0.8155 - val_loss: 0.6686 - val_categorical_accuracy: 0.6800
Epoch 455/500
21/21 [==============================] - 14s 674ms/step - loss: 0.4118 - categorical_acc
uracy: 0.8592 - val_loss: 0.5904 - val_categorical_accuracy: 0.7000
Epoch 456/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4532 - categorical_acc
uracy: 0.8447 - val_loss: 0.7660 - val_categorical_accuracy: 0.7000
Epoch 457/500
```

```
21/21 [==============================] - 14s 657ms/step - loss: 0.4634 - categorical_acc
uracy: 0.8010 - val_loss: 0.6104 - val_categorical_accuracy: 0.6800
Epoch 458/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4642 - categorical_acc
uracy: 0.8398 - val_loss: 0.6432 - val_categorical_accuracy: 0.7000
Epoch 459/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4838 - categorical_acc
uracy: 0.7767 - val_loss: 0.6700 - val_categorical_accuracy: 0.7400
Epoch 460/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4575 - categorical_acc
uracy: 0.8350 - val_loss: 0.6537 - val_categorical_accuracy: 0.7200
Epoch 461/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4658 - categorical_acc
uracy: 0.7913 - val_loss: 0.6684 - val_categorical_accuracy: 0.7400
Epoch 462/500
21/21 [==============================] - 14s 661ms/step - loss: 0.4274 - categorical_acc
uracy: 0.8447 - val_loss: 0.5526 - val_categorical_accuracy: 0.7200
Epoch 463/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4246 - categorical_acc
uracy: 0.8495 - val_loss: 0.6498 - val_categorical_accuracy: 0.7000
Epoch 464/500
21/21 [==============================] - 14s 663ms/step - loss: 0.4450 - categorical_acc
uracy: 0.8107 - val_loss: 0.6831 - val_categorical_accuracy: 0.6800
Epoch 465/500
21/21 [==============================] - 14s 669ms/step - loss: 0.4476 - categorical_acc
uracy: 0.8048 - val_loss: 0.5975 - val_categorical_accuracy: 0.7200
Epoch 466/500
21/21 [==============================] - 14s 663ms/step - loss: 0.4524 - categorical_acc
uracy: 0.8252 - val_loss: 0.5550 - val_categorical_accuracy: 0.7400
Epoch 467/500
21/21 [==============================] - 14s 663ms/step - loss: 0.4627 - categorical_acc
uracy: 0.8107 - val_loss: 0.6268 - val_categorical_accuracy: 0.7400
Epoch 468/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4336 - categorical_acc
uracy: 0.8398 - val_loss: 0.5602 - val_categorical_accuracy: 0.7400
Epoch 469/500
21/21 [==============================] - 14s 674ms/step - loss: 0.4433 - categorical_acc
uracy: 0.8252 - val_loss: 0.6359 - val_categorical_accuracy: 0.7600
Epoch 470/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4208 - categorical_acc
uracy: 0.8155 - val_loss: 0.7417 - val_categorical_accuracy: 0.7200
Epoch 471/500
21/21 [==============================] - 14s 662ms/step - loss: 0.4271 - categorical_acc
uracy: 0.8495 - val_loss: 0.7297 - val_categorical_accuracy: 0.7600
Epoch 472/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4317 - categorical_acc
uracy: 0.8107 - val_loss: 0.6838 - val_categorical_accuracy: 0.7000
Epoch 473/500
21/21 [==============================] - 14s 662ms/step - loss: 0.4570 - categorical_acc
uracy: 0.8058 - val_loss: 0.5992 - val_categorical_accuracy: 0.7400
Epoch 474/500
21/21 [==============================] - 14s 667ms/step - loss: 0.4235 - categorical_acc
uracy: 0.8350 - val_loss: 0.7189 - val_categorical_accuracy: 0.6200
Epoch 475/500
21/21 [==============================] - 14s 668ms/step - loss: 0.4441 - categorical_acc
uracy: 0.8350 - val_loss: 0.5782 - val_categorical_accuracy: 0.7400
Epoch 476/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4853 - categorical_acc
uracy: 0.8398 - val_loss: 0.6689 - val_categorical_accuracy: 0.6800
Epoch 477/500
```

```
21/21 [==============================] - 14s 688ms/step - loss: 0.4188 - categorical_acc
uracy: 0.8398 - val_loss: 0.6603 - val_categorical_accuracy: 0.7400
Epoch 478/500
21/21 [==============================] - 14s 661ms/step - loss: 0.4654 - categorical_acc
uracy: 0.8155 - val_loss: 0.6763 - val_categorical_accuracy: 0.7000
Epoch 479/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4432 - categorical_acc
uracy: 0.8544 - val_loss: 0.6302 - val_categorical_accuracy: 0.7400
Epoch 480/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4469 - categorical_acc
uracy: 0.8447 - val_loss: 0.6427 - val_categorical_accuracy: 0.6800
Epoch 481/500
21/21 [==============================] - 14s 661ms/step - loss: 0.3886 - categorical_acc
uracy: 0.8495 - val_loss: 0.6396 - val_categorical_accuracy: 0.7200
Epoch 482/500
21/21 [==============================] - 14s 659ms/step - loss: 0.4430 - categorical_acc
uracy: 0.8350 - val_loss: 0.6812 - val_categorical_accuracy: 0.7200
Epoch 483/500
21/21 [==============================] - 14s 657ms/step - loss: 0.4275 - categorical_acc
uracy: 0.8350 - val_loss: 0.6431 - val_categorical_accuracy: 0.7200
Epoch 484/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4867 - categorical_acc
uracy: 0.7816 - val_loss: 0.6852 - val_categorical_accuracy: 0.6600
Epoch 485/500
21/21 [==============================] - 14s 675ms/step - loss: 0.4550 - categorical_acc
uracy: 0.8544 - val_loss: 0.6087 - val_categorical_accuracy: 0.7600
Epoch 486/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4209 - categorical_acc
uracy: 0.8350 - val_loss: 0.6606 - val_categorical_accuracy: 0.6800
Epoch 487/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4238 - categorical_acc
uracy: 0.8350 - val_loss: 0.6702 - val_categorical_accuracy: 0.6400
Epoch 488/500
21/21 [==============================] - 14s 664ms/step - loss: 0.4179 - categorical_acc
uracy: 0.8592 - val_loss: 0.5993 - val_categorical_accuracy: 0.7000
Epoch 489/500
21/21 [==============================] - 14s 659ms/step - loss: 0.3983 - categorical_acc
uracy: 0.8544 - val_loss: 0.6044 - val_categorical_accuracy: 0.7000
Epoch 490/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4180 - categorical_acc
uracy: 0.8447 - val_loss: 0.5570 - val_categorical_accuracy: 0.7600
Epoch 491/500
21/21 [==============================] - 14s 670ms/step - loss: 0.4295 - categorical_acc
uracy: 0.8476 - val_loss: 0.6415 - val_categorical_accuracy: 0.7000
Epoch 492/500
21/21 [==============================] - 14s 679ms/step - loss: 0.4208 - categorical_acc
uracy: 0.8495 - val_loss: 0.6066 - val_categorical_accuracy: 0.7000
Epoch 493/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4297 - categorical_acc
uracy: 0.8544 - val_loss: 0.7514 - val_categorical_accuracy: 0.6600
Epoch 494/500
21/21 [==============================] - 14s 656ms/step - loss: 0.4387 - categorical_acc
uracy: 0.8252 - val_loss: 0.6310 - val_categorical_accuracy: 0.6800
Epoch 495/500
21/21 [==============================] - 14s 662ms/step - loss: 0.4497 - categorical_acc
uracy: 0.8155 - val_loss: 0.6661 - val_categorical_accuracy: 0.6400
Epoch 496/500
21/21 [==============================] - 14s 655ms/step - loss: 0.4174 - categorical_acc
uracy: 0.8252 - val_loss: 0.5709 - val_categorical_accuracy: 0.7600
Epoch 497/500
```

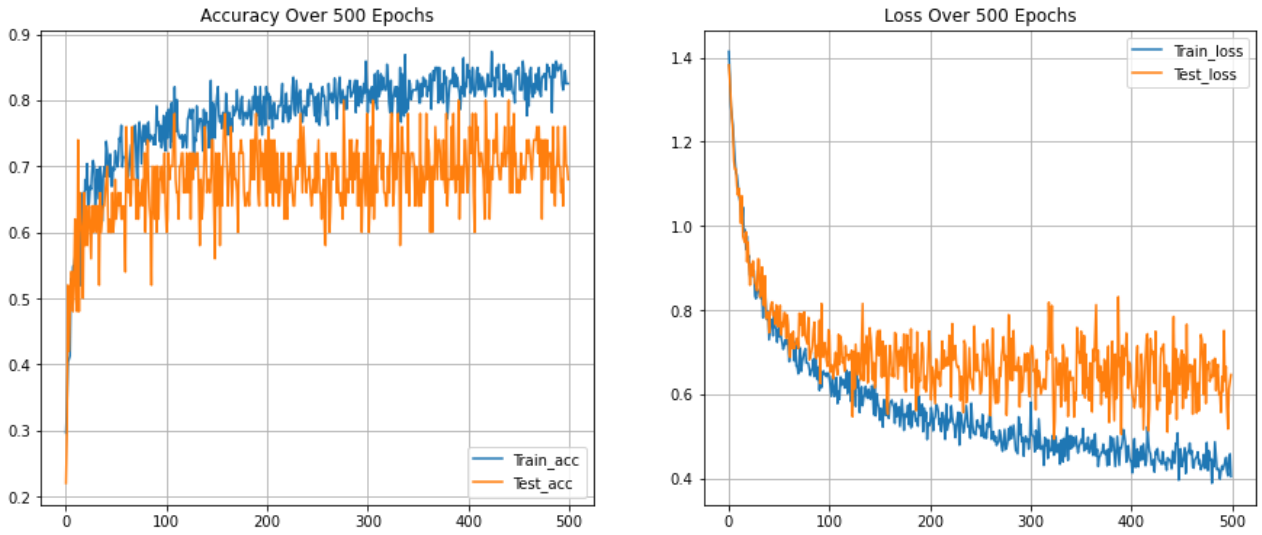
```
21/21 [==============================] - 14s 656ms/step - loss: 0.4063 - categorical_acc
uracy: 0.8447 - val_loss: 0.5175 - val_categorical_accuracy: 0.7600
Epoch 498/500
21/21 [==============================] - 14s 658ms/step - loss: 0.4515 - categorical_acc
uracy: 0.8252 - val_loss: 0.6129 - val_categorical_accuracy: 0.7000
Epoch 499/500
21/21 [==============================] - 14s 661ms/step - loss: 0.4582 - categorical_acc
uracy: 0.8252 - val_loss: 0.6290 - val_categorical_accuracy: 0.7000
Epoch 500/500
21/21 [==============================] - 14s 660ms/step - loss: 0.4044 - categorical_acc
uracy: 0.8252 - val_loss: 0.6464 - val_categorical_accuracy: 0.6800
```

[5 points] Plot Accuracy and Loss During Training

In [126…

```
import matplotlib.pyplot as plt

fig, (ax1, ax2) = plt.subplots(1, 2)
fig.set_figheight(6)
fig.set_figwidth(15)
ax1.plot(res.history['categorical_accuracy'])
ax1.plot(res.history['val_categorical_accuracy'])
ax1.set_title('Accuracy Over ' + str(NUM_EPOCHS) + ' Epochs')
ax1.legend(['Train_acc', 'Test_acc'], loc='lower right')
ax1.grid(True)
ax2.set_title('Loss Over ' + str(NUM_EPOCHS) + ' Epochs')
ax2.plot(res.history['loss'])
ax2.plot(res.history['val_loss'])
ax2.legend(['Train_loss', 'Test_loss'], loc='upper right')
ax2.grid(True)
plt.show()
```



Testing Model

In [127…

```
test_datagen = ImageDataGenerator(rescale=1. / 255)

eval_generator = test_datagen.flow_from_directory(TEST_DIR,target_size=IMAGE_SIZE,
                                                  batch_size=1,shuffle=True,seed=42,cla
eval_generator.reset()
print(len(eval_generator))
x = model.evaluate_generator(eval_generator,steps = np.ceil(len(eval_generator)),
                             use_multiprocessing = False,verbose = 1,workers=1)
```

```
print('Test loss:' , x[0])
print('Test accuracy:',x[1])
```

```
Found 36 images belonging to 4 classes.
36
36/36 [==============================] - 3s 69ms/step - loss: 0.7342 - categorical_accur
acy: 0.6944
Test loss: 0.7342052459716797
Test accuracy: 0.6944444179534912
```

Model 2: AlexNet

[10 points] Build Model

Hint: Starting from a pre-trained model typically helps performance on a new task, e.g. starting with weights obtained by training on ImageNet.

In [128…

```
# from https://towardsdatascience.com/implementing-alexnet-cnn-architecture-using-tenso
model = tf.keras.models.Sequential([
    tf.keras.layers.Conv2D(filters=96, kernel_size=(11,11), strides=(4,4), activation='
    tf.keras.layers.BatchNormalization(),
    tf.keras.layers.MaxPool2D(pool_size=(3,3), strides=(2,2)),
    tf.keras.layers.Conv2D(filters=256, kernel_size=(5,5), strides=(1,1), activation='r
    tf.keras.layers.BatchNormalization(),
    tf.keras.layers.MaxPool2D(pool_size=(3,3), strides=(2,2)),
    tf.keras.layers.Conv2D(filters=384, kernel_size=(3,3), strides=(1,1), activation='r
    tf.keras.layers.BatchNormalization(),
    tf.keras.layers.Conv2D(filters=384, kernel_size=(3,3), strides=(1,1), activation='r
    tf.keras.layers.BatchNormalization(),
    tf.keras.layers.Conv2D(filters=256, kernel_size=(3,3), strides=(1,1), activation='r
    tf.keras.layers.BatchNormalization(),
    tf.keras.layers.MaxPool2D(pool_size=(3,3), strides=(2,2)),
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(4096, activation='relu'),
    tf.keras.layers.Dropout(0.5),
    tf.keras.layers.Dense(4096, activation='relu'),
    tf.keras.layers.Dropout(0.5),
    tf.keras.layers.Dense(4, activation='softmax')
])
model.compile(loss='categorical_crossentropy', optimizer=tf.optimizers.SGD(lr=1e-7), me
```

In [129…

```
model.summary()
```

```
Model: "sequential_30"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_50 (Conv2D)           (None, 54, 54, 96)        34944
_________________________________________________________________
batch_normalization_50 (Batc (None, 54, 54, 96)        384
_________________________________________________________________
max_pooling2d_30 (MaxPooling (None, 26, 26, 96)        0
_________________________________________________________________
conv2d_51 (Conv2D)           (None, 26, 26, 256)       614656
_________________________________________________________________
```

```
batch_normalization_51 (Batc (None, 26, 26, 256)       1024
_________________________________________________________________
max_pooling2d_31 (MaxPooling (None, 12, 12, 256)       0
_________________________________________________________________
conv2d_52 (Conv2D)           (None, 12, 12, 384)       885120
_________________________________________________________________
batch_normalization_52 (Batc (None, 12, 12, 384)       1536
_________________________________________________________________
conv2d_53 (Conv2D)           (None, 12, 12, 384)       1327488
_________________________________________________________________
batch_normalization_53 (Batc (None, 12, 12, 384)       1536
_________________________________________________________________
conv2d_54 (Conv2D)           (None, 12, 12, 256)       884992
_________________________________________________________________
batch_normalization_54 (Batc (None, 12, 12, 256)       1024
_________________________________________________________________
max_pooling2d_32 (MaxPooling (None, 5, 5, 256)         0
_________________________________________________________________
flatten_30 (Flatten)         (None, 6400)              0
_________________________________________________________________
dense_87 (Dense)             (None, 4096)              26218496
_________________________________________________________________
dropout_51 (Dropout)         (None, 4096)              0
_________________________________________________________________
dense_88 (Dense)             (None, 4096)              16781312
_________________________________________________________________
dropout_52 (Dropout)         (None, 4096)              0
_________________________________________________________________
dense_89 (Dense)             (None, 4)                 16388
=================================================================
Total params: 46,768,900
Trainable params: 46,766,148
Non-trainable params: 2,752
_________________________________________________________________
```

[5 points] Train Model

In [ ]:

```
#FIT MODEL
print(len(train_batches))
print(len(valid_batches))


STEP_SIZE_TRAIN=train_batches.n//train_batches.batch_size
STEP_SIZE_VALID=valid_batches.n//valid_batches.batch_size

NUM_EPOCHS = 100


res = model.fit(train_batches, epochs=NUM_EPOCHS, steps_per_epoch=STEP_SIZE_TRAIN, \
          validation_data=valid_batches, validation_steps=STEP_SIZE_VALID)
```

```
22
6
Epoch 1/100
21/21 [==============================] - 8s 374ms/step - loss: 3.2500 - categorical_accu
racy: 0.2476 - val_loss: 1.4232 - val_categorical_accuracy: 0.2600
Epoch 2/100
21/21 [==============================] - 8s 371ms/step - loss: 3.0390 - categorical_accu
racy: 0.2718 - val_loss: 1.4285 - val_categorical_accuracy: 0.2600
```

```
Epoch 3/100
21/21 [==============================] - 8s 370ms/step - loss: 3.2938 - categorical_accu
racy: 0.2476 - val_loss: 1.4257 - val_categorical_accuracy: 0.2600
Epoch 4/100
21/21 [==============================] - 8s 375ms/step - loss: 3.0958 - categorical_accu
racy: 0.2718 - val_loss: 1.4125 - val_categorical_accuracy: 0.2800
Epoch 5/100
21/21 [==============================] - 8s 374ms/step - loss: 3.0334 - categorical_accu
racy: 0.2573 - val_loss: 1.4218 - val_categorical_accuracy: 0.2800
Epoch 6/100
21/21 [==============================] - 8s 376ms/step - loss: 3.2283 - categorical_accu
racy: 0.2087 - val_loss: 1.4867 - val_categorical_accuracy: 0.2600
Epoch 7/100
21/21 [==============================] - 8s 375ms/step - loss: 2.9507 - categorical_accu
racy: 0.2282 - val_loss: 1.4934 - val_categorical_accuracy: 0.2600
Epoch 8/100
21/21 [==============================] - 8s 373ms/step - loss: 2.9717 - categorical_accu
racy: 0.2816 - val_loss: 1.5868 - val_categorical_accuracy: 0.2400
Epoch 9/100
21/21 [==============================] - 8s 376ms/step - loss: 3.0975 - categorical_accu
racy: 0.1942 - val_loss: 1.5387 - val_categorical_accuracy: 0.2800
Epoch 10/100
21/21 [==============================] - 8s 376ms/step - loss: 2.7252 - categorical_accu
racy: 0.3010 - val_loss: 1.5172 - val_categorical_accuracy: 0.3600
Epoch 11/100
21/21 [==============================] - 8s 378ms/step - loss: 2.8656 - categorical_accu
racy: 0.2571 - val_loss: 1.5545 - val_categorical_accuracy: 0.3400
Epoch 12/100
21/21 [==============================] - 8s 376ms/step - loss: 3.1151 - categorical_accu
racy: 0.1942 - val_loss: 1.5722 - val_categorical_accuracy: 0.3000
Epoch 13/100
21/21 [==============================] - 8s 382ms/step - loss: 3.1457 - categorical_accu
racy: 0.2952 - val_loss: 1.7581 - val_categorical_accuracy: 0.2600
Epoch 14/100
21/21 [==============================] - 8s 372ms/step - loss: 3.0388 - categorical_accu
racy: 0.2524 - val_loss: 1.7039 - val_categorical_accuracy: 0.3000
Epoch 15/100
21/21 [==============================] - 8s 368ms/step - loss: 2.9528 - categorical_accu
racy: 0.2621 - val_loss: 1.7320 - val_categorical_accuracy: 0.3200
Epoch 16/100
21/21 [==============================] - 8s 374ms/step - loss: 2.9095 - categorical_accu
racy: 0.2718 - val_loss: 1.6356 - val_categorical_accuracy: 0.3000
Epoch 17/100
21/21 [==============================] - 8s 376ms/step - loss: 2.9198 - categorical_accu
racy: 0.3107 - val_loss: 1.6825 - val_categorical_accuracy: 0.3000
Epoch 18/100
21/21 [==============================] - 8s 376ms/step - loss: 2.8891 - categorical_accu
racy: 0.3010 - val_loss: 1.6258 - val_categorical_accuracy: 0.3400
Epoch 19/100
21/21 [==============================] - 8s 387ms/step - loss: 2.6624 - categorical_accu
racy: 0.3143 - val_loss: 1.7134 - val_categorical_accuracy: 0.2400
Epoch 20/100
21/21 [==============================] - 8s 378ms/step - loss: 3.4338 - categorical_accu
racy: 0.2087 - val_loss: 1.6353 - val_categorical_accuracy: 0.2800
Epoch 21/100
21/21 [==============================] - 8s 375ms/step - loss: 3.0901 - categorical_accu
racy: 0.2427 - val_loss: 1.6709 - val_categorical_accuracy: 0.2800
Epoch 22/100
21/21 [==============================] - 8s 376ms/step - loss: 2.7610 - categorical_accu
racy: 0.3010 - val_loss: 1.6204 - val_categorical_accuracy: 0.3200
```

```
Epoch 23/100
21/21 [==============================] - 8s 368ms/step - loss: 2.9169 - categorical_accu
racy: 0.2670 - val_loss: 1.5241 - val_categorical_accuracy: 0.3000
Epoch 24/100
21/21 [==============================] - 8s 376ms/step - loss: 2.8818 - categorical_accu
racy: 0.2864 - val_loss: 1.6931 - val_categorical_accuracy: 0.2400
Epoch 25/100
21/21 [==============================] - 8s 383ms/step - loss: 3.1545 - categorical_accu
racy: 0.2427 - val_loss: 1.4648 - val_categorical_accuracy: 0.4000
Epoch 26/100
21/21 [==============================] - 8s 375ms/step - loss: 3.0472 - categorical_accu
racy: 0.2184 - val_loss: 1.4986 - val_categorical_accuracy: 0.3400
Epoch 27/100
21/21 [==============================] - 8s 378ms/step - loss: 3.0456 - categorical_accu
racy: 0.2864 - val_loss: 1.6133 - val_categorical_accuracy: 0.2800
Epoch 28/100
21/21 [==============================] - 8s 378ms/step - loss: 2.8187 - categorical_accu
racy: 0.2573 - val_loss: 1.5099 - val_categorical_accuracy: 0.3200
Epoch 29/100
21/21 [==============================] - 8s 371ms/step - loss: 3.0556 - categorical_accu
racy: 0.2427 - val_loss: 1.5298 - val_categorical_accuracy: 0.3400
Epoch 30/100
21/21 [==============================] - 8s 382ms/step - loss: 3.3274 - categorical_accu
racy: 0.1748 - val_loss: 1.5871 - val_categorical_accuracy: 0.3000
Epoch 31/100
21/21 [==============================] - 8s 382ms/step - loss: 2.9146 - categorical_accu
racy: 0.2136 - val_loss: 1.6541 - val_categorical_accuracy: 0.2600
Epoch 32/100
21/21 [==============================] - 8s 377ms/step - loss: 2.6200 - categorical_accu
racy: 0.3252 - val_loss: 1.7945 - val_categorical_accuracy: 0.1600
Epoch 33/100
21/21 [==============================] - 8s 372ms/step - loss: 2.8069 - categorical_accu
racy: 0.2913 - val_loss: 1.6282 - val_categorical_accuracy: 0.2400
Epoch 34/100
21/21 [==============================] - 8s 375ms/step - loss: 2.6941 - categorical_accu
racy: 0.2816 - val_loss: 1.4641 - val_categorical_accuracy: 0.3600
Epoch 35/100
21/21 [==============================] - 8s 367ms/step - loss: 2.9790 - categorical_accu
racy: 0.2379 - val_loss: 1.5833 - val_categorical_accuracy: 0.2800
Epoch 36/100
21/21 [==============================] - 8s 380ms/step - loss: 2.9263 - categorical_accu
racy: 0.2864 - val_loss: 1.6305 - val_categorical_accuracy: 0.3400
Epoch 37/100
21/21 [==============================] - 8s 368ms/step - loss: 2.8294 - categorical_accu
racy: 0.2767 - val_loss: 1.7364 - val_categorical_accuracy: 0.2400
Epoch 38/100
21/21 [==============================] - 8s 374ms/step - loss: 2.9047 - categorical_accu
racy: 0.2864 - val_loss: 1.4907 - val_categorical_accuracy: 0.3000
Epoch 39/100
21/21 [==============================] - 8s 370ms/step - loss: 2.7538 - categorical_accu
racy: 0.2864 - val_loss: 1.5621 - val_categorical_accuracy: 0.2400
Epoch 40/100
21/21 [==============================] - 8s 374ms/step - loss: 2.9262 - categorical_accu
racy: 0.2718 - val_loss: 1.4995 - val_categorical_accuracy: 0.2400
Epoch 41/100
21/21 [==============================] - 8s 372ms/step - loss: 2.7213 - categorical_accu
racy: 0.3010 - val_loss: 1.7151 - val_categorical_accuracy: 0.2600
Epoch 42/100
21/21 [==============================] - 8s 373ms/step - loss: 2.5731 - categorical_accu
racy: 0.2961 - val_loss: 1.4888 - val_categorical_accuracy: 0.3200
```

```
Epoch 43/100
21/21 [==============================] - 8s 373ms/step - loss: 2.9637 - categorical_accu
racy: 0.2621 - val_loss: 1.6893 - val_categorical_accuracy: 0.2600
Epoch 44/100
21/21 [==============================] - 8s 369ms/step - loss: 3.3102 - categorical_accu
racy: 0.2282 - val_loss: 1.5662 - val_categorical_accuracy: 0.3000
Epoch 45/100
21/21 [==============================] - 8s 367ms/step - loss: 2.9954 - categorical_accu
racy: 0.2767 - val_loss: 1.5912 - val_categorical_accuracy: 0.3000
Epoch 46/100
21/21 [==============================] - 8s 373ms/step - loss: 2.9564 - categorical_accu
racy: 0.2718 - val_loss: 1.6003 - val_categorical_accuracy: 0.3000
Epoch 47/100
21/21 [==============================] - 8s 373ms/step - loss: 2.7251 - categorical_accu
racy: 0.2670 - val_loss: 1.7495 - val_categorical_accuracy: 0.2800
Epoch 48/100
21/21 [==============================] - 8s 378ms/step - loss: 3.0171 - categorical_accu
racy: 0.2476 - val_loss: 1.5963 - val_categorical_accuracy: 0.3200
Epoch 49/100
21/21 [==============================] - 8s 367ms/step - loss: 2.8032 - categorical_accu
racy: 0.2767 - val_loss: 1.5506 - val_categorical_accuracy: 0.2400
Epoch 50/100
21/21 [==============================] - 8s 374ms/step - loss: 2.8737 - categorical_accu
racy: 0.2427 - val_loss: 1.5835 - val_categorical_accuracy: 0.2800
Epoch 51/100
21/21 [==============================] - 8s 373ms/step - loss: 2.8583 - categorical_accu
racy: 0.2427 - val_loss: 1.4519 - val_categorical_accuracy: 0.3400
Epoch 52/100
21/21 [==============================] - 8s 373ms/step - loss: 3.1376 - categorical_accu
racy: 0.2379 - val_loss: 1.6366 - val_categorical_accuracy: 0.2800
Epoch 53/100
21/21 [==============================] - 8s 373ms/step - loss: 2.9074 - categorical_accu
racy: 0.2330 - val_loss: 1.5327 - val_categorical_accuracy: 0.3000
Epoch 54/100
21/21 [==============================] - 8s 369ms/step - loss: 2.7461 - categorical_accu
racy: 0.2718 - val_loss: 1.6341 - val_categorical_accuracy: 0.3000
Epoch 55/100
21/21 [==============================] - 8s 371ms/step - loss: 2.8589 - categorical_accu
racy: 0.1990 - val_loss: 1.3422 - val_categorical_accuracy: 0.4400
Epoch 56/100
21/21 [==============================] - 8s 383ms/step - loss: 2.4142 - categorical_accu
racy: 0.3447 - val_loss: 1.6218 - val_categorical_accuracy: 0.2800
Epoch 57/100
21/21 [==============================] - 8s 370ms/step - loss: 2.9390 - categorical_accu
racy: 0.2136 - val_loss: 1.5937 - val_categorical_accuracy: 0.3800
Epoch 58/100
21/21 [==============================] - 8s 374ms/step - loss: 2.5998 - categorical_accu
racy: 0.2476 - val_loss: 1.5012 - val_categorical_accuracy: 0.2800
Epoch 59/100
21/21 [==============================] - 8s 374ms/step - loss: 2.7625 - categorical_accu
racy: 0.2767 - val_loss: 1.5073 - val_categorical_accuracy: 0.2800
Epoch 60/100
21/21 [==============================] - 8s 367ms/step - loss: 3.0342 - categorical_accu
racy: 0.2330 - val_loss: 1.4351 - val_categorical_accuracy: 0.3800
Epoch 61/100
21/21 [==============================] - 8s 367ms/step - loss: 2.8924 - categorical_accu
racy: 0.2621 - val_loss: 1.3189 - val_categorical_accuracy: 0.4400
Epoch 62/100
21/21 [==============================] - 8s 372ms/step - loss: 2.8798 - categorical_accu
racy: 0.2670 - val_loss: 1.3600 - val_categorical_accuracy: 0.3400
```

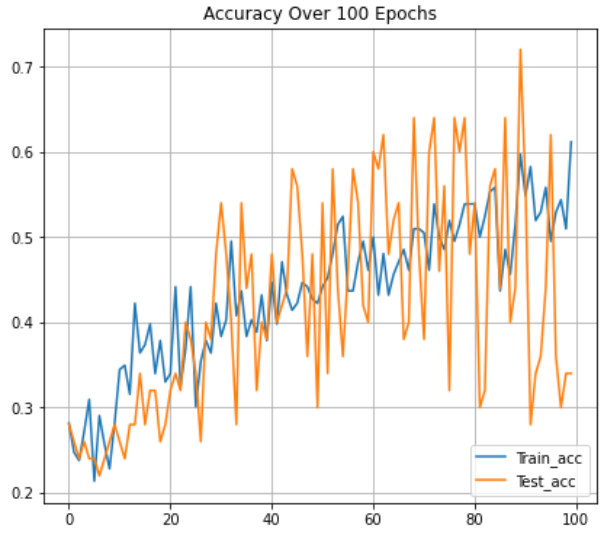
```
Epoch 63/100
21/21 [==============================] - 8s 380ms/step - loss: 3.0546 - categorical_accu
racy: 0.2476 - val_loss: 1.4634 - val_categorical_accuracy: 0.2800
Epoch 64/100
21/21 [==============================] - 8s 376ms/step - loss: 2.9795 - categorical_accu
racy: 0.2330 - val_loss: 1.3874 - val_categorical_accuracy: 0.3800
Epoch 65/100
21/21 [==============================] - 8s 377ms/step - loss: 2.6955 - categorical_accu
racy: 0.2379 - val_loss: 1.5295 - val_categorical_accuracy: 0.2600
Epoch 66/100
21/21 [==============================] - 8s 368ms/step - loss: 2.6305 - categorical_accu
racy: 0.2961 - val_loss: 1.5572 - val_categorical_accuracy: 0.3000
Epoch 67/100
21/21 [==============================] - 9s 430ms/step - loss: 2.9958 - categorical_accu
racy: 0.2670 - val_loss: 1.3838 - val_categorical_accuracy: 0.4000
Epoch 68/100
21/21 [==============================] - 8s 389ms/step - loss: 2.5636 - categorical_accu
racy: 0.3544 - val_loss: 1.5708 - val_categorical_accuracy: 0.3000
Epoch 69/100
21/21 [==============================] - 8s 374ms/step - loss: 2.7185 - categorical_accu
racy: 0.3350 - val_loss: 1.4388 - val_categorical_accuracy: 0.3200
Epoch 70/100
21/21 [==============================] - 8s 370ms/step - loss: 2.6305 - categorical_accu
racy: 0.2816 - val_loss: 1.4986 - val_categorical_accuracy: 0.2600
Epoch 71/100
21/21 [==============================] - 8s 392ms/step - loss: 2.8454 - categorical_accu
racy: 0.3010 - val_loss: 1.6267 - val_categorical_accuracy: 0.3200
Epoch 72/100
21/21 [==============================] - ETA: 0s - loss: 2.9368 - categorical_accuracy:
0.2573
```

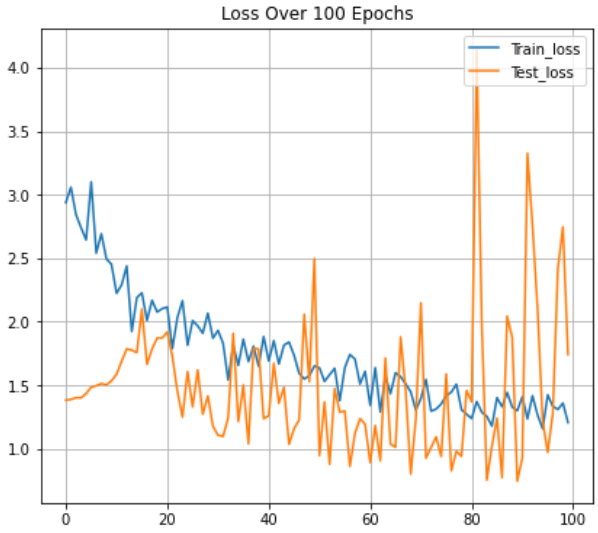
[5 points] Plot Accuracy and Loss During Training

In [70]:

```
import matplotlib.pyplot as plt

fig, (ax1, ax2) = plt.subplots(1, 2)
fig.set_figheight(6)
fig.set_figwidth(15)
ax1.plot(res.history['categorical_accuracy'])
ax1.plot(res.history['val_categorical_accuracy'])
ax1.set_title('Accuracy Over ' + str(NUM_EPOCHS) + ' Epochs')
ax1.legend(['Train_acc', 'Test_acc'], loc='lower right')
ax1.grid(True)
ax2.set_title('Loss Over ' + str(NUM_EPOCHS) + ' Epochs')
ax2.plot(res.history['loss'])
ax2.plot(res.history['val_loss'])
ax2.legend(['Train_loss', 'Test_loss'], loc='upper right')
ax2.grid(True)
plt.show()
```





Testing Model

In [66]:

```
test_datagen = ImageDataGenerator(rescale=1. / 255)

eval_generator = test_datagen.flow_from_directory(TEST_DIR,target_size=IMAGE_SIZE,
                                                  batch_size=1,shuffle=True,seed=42,cla
eval_generator.reset()
print(len(eval_generator))
x = model.evaluate_generator(eval_generator,steps = np.ceil(len(eval_generator)),
                             use_multiprocessing = False,verbose = 1,workers=1)
print('Test loss:' , x[0])
print('Test accuracy:',x[1])
```

```
Found 36 images belonging to 4 classes.
36
36/36 [==============================] - 1s 23ms/step - loss: 1.9850 - categorical_accur
acy: 0.5278
Test loss: 1.9850109815597534
Test accuracy: 0.5277777910232544
```