```
# to prevent unnecessary warnings
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)

# TensorFlow and tf.keras
import tensorflow as tf

# Helper libraries
import numpy as np
import matplotlib.pyplot as plt
import os
import subprocess
import cv2
import json
import requests
from tqdm import tqdm

print(tf.__version__)
```

```
2.8.2
```

```
fashion_mnist = tf.keras.datasets.fashion_mnist
(train_images, train_labels), (test_images, test_labels) =
fashion_mnist.load_data()

class_names = ['T-shirt/top', 'Trouser', 'Pullover', 'Dress', 'Coat',
'Sandal', 'Shirt', 'Sneaker', 'Bag', 'Ankle boot']

print('\nTrain_images.shape: {}, of {}'.format(train_images.shape,
train_images.dtype))
print('Test_images.shape: {}, of {}'.format(test_images.shape,
test_images.dtype))
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/train-labels-idx1-ubyte.gz
32768/29515 [==============================] - 0s 0us/step
40960/29515 [==========================================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/train-images-idx3-ubyte.gz
26427392/26421880 [==============================] - 0s 0us/step
26435584/26421880 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/t10k-labels-idx1-ubyte.gz
16384/5148
[==============================================================================
==========================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/t10k-images-idx3-ubyte.gz
4423680/4422102 [==============================] - 0s 0us/step
4431872/4422102 [==============================] - 0s 0us/step
```

```
Train_images.shape: (60000, 28, 28), of uint8
Test_images.shape: (10000, 28, 28), of uint8
```

#Reshape data

```
train_images_3ch = np.stack([train_images]*3, axis=-1)
test_images_3ch = np.stack([test_images]*3, axis=-1)

print('\nTrain_images.shape: {}, of {}'.format(train_images_3ch.shape,
train_images_3ch.dtype))
print('Test_images.shape: {}, of {}'.format(test_images_3ch.shape,
test_images_3ch.dtype))

#imagenet competition was for colored images hence 3 channels


Train_images.shape: (60000, 28, 28, 3), of uint8
Test_images.shape: (10000, 28, 28, 3), of uint8
```

#Resizing image

###The minimum image size expected by the VGG model is 32x32 so we need to resize our images

```
import cv2

def resize_image_array(img, img_size_dims):
    img = cv2.resize(img, dsize=img_size_dims,
    interpolation=cv2.INTER_CUBIC)
    img = np.array(img, dtype=np.float32)
    return img

%%time

IMG_DIMS = (32, 32)

train_images_3ch = np.array([resize_image_array(img,
img_size_dims=IMG_DIMS) for img in train_images_3ch])
test_images_3ch = np.array([resize_image_array(img,
img_size_dims=IMG_DIMS) for img in test_images_3ch])

print('\nTrain_images.shape: {}, of {}'.format(train_images_3ch.shape,
train_images_3ch.dtype))
print('Test_images.shape: {}, of {}'.format(test_images_3ch.shape,
test_images_3ch.dtype))


Train_images.shape: (60000, 32, 32, 3), of float32
Test_images.shape: (10000, 32, 32, 3), of float32
```

```
CPU times: user 1.5 s, sys: 663 ms, total: 2.16 s
Wall time: 2.21 s
```

#Build CNN Model

```
# define input shape
INPUT_SHAPE = (32, 32, 3)

# get the VGG19 model
vgg_layers = tf.keras.applications.vgg19.VGG19(weights='imagenet',
include_top=False,
input_shape=INPUT_SHAPE)
#we are adding our own layer
vgg_layers.summary()
#include_top=False = we will add our own last layer
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/vgg19/vgg19_weights_tf_dim_ordering_tf_kernels_notop.h5
80142336/80134624 [==============================] - 0s 0us/step
80150528/80134624 [==============================] - 0s 0us/step
Model: "vgg19"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 32, 32, 3)]       0

 block1_conv1 (Conv2D)       (None, 32, 32, 64)        1792

 block1_conv2 (Conv2D)       (None, 32, 32, 64)        36928

 block1_pool (MaxPooling2D)  (None, 16, 16, 64)        0

 block2_conv1 (Conv2D)       (None, 16, 16, 128)       73856

 block2_conv2 (Conv2D)       (None, 16, 16, 128)       147584

 block2_pool (MaxPooling2D)  (None, 8, 8, 128)         0

 block3_conv1 (Conv2D)       (None, 8, 8, 256)         295168

 block3_conv2 (Conv2D)       (None, 8, 8, 256)         590080

 block3_conv3 (Conv2D)       (None, 8, 8, 256)         590080

 block3_conv4 (Conv2D)       (None, 8, 8, 256)         590080

 block3_pool (MaxPooling2D)  (None, 4, 4, 256)         0

 block4_conv1 (Conv2D)       (None, 4, 4, 512)         1180160
```

```
 block4_conv2 (Conv2D)       (None, 4, 4, 512)         2359808

 block4_conv3 (Conv2D)       (None, 4, 4, 512)         2359808

 block4_conv4 (Conv2D)       (None, 4, 4, 512)         2359808

 block4_pool (MaxPooling2D)  (None, 2, 2, 512)         0

 block5_conv1 (Conv2D)       (None, 2, 2, 512)         2359808

 block5_conv2 (Conv2D)       (None, 2, 2, 512)         2359808

 block5_conv3 (Conv2D)       (None, 2, 2, 512)         2359808

 block5_conv4 (Conv2D)       (None, 2, 2, 512)         2359808

 block5_pool (MaxPooling2D)  (None, 1, 1, 512)         0

=================================================================
Total params: 20,024,384
Trainable params: 20,024,384
Non-trainable params: 0
_________________________________________________________________
```

#Fine tuning

```
# Fine-tune all the layers
for layer in vgg_layers.layers:
  layer.trainable = True #we are training layers

# Check the trainable status of the individual layers
for layer in vgg_layers.layers:
  print(layer, layer.trainable)
```

```
<keras.engine.input_layer.InputLayer object at 0x7f0a33341450> True
<keras.layers.convolutional.Conv2D object at 0x7f0a25136d50> True
<keras.layers.convolutional.Conv2D object at 0x7f0a24e65510> True
<keras.layers.pooling.MaxPooling2D object at 0x7f0a25126d50> True
<keras.layers.convolutional.Conv2D object at 0x7f0a250e2250> True
<keras.layers.convolutional.Conv2D object at 0x7f0a250e5b50> True
<keras.layers.pooling.MaxPooling2D object at 0x7f0a25070350> True
<keras.layers.convolutional.Conv2D object at 0x7f0a2506cd10> True
<keras.layers.convolutional.Conv2D object at 0x7f0a32cf1850> True
<keras.layers.convolutional.Conv2D object at 0x7f0a2507e810> True
<keras.layers.convolutional.Conv2D object at 0x7f0a25082bd0> True
<keras.layers.pooling.MaxPooling2D object at 0x7f0a2506c9d0> True
<keras.layers.convolutional.Conv2D object at 0x7f0a25089710> True
<keras.layers.convolutional.Conv2D object at 0x7f0a25092290> True
```

```
<keras.layers.convolutional.Conv2D object at 0x7f0a250890d0> True
<keras.layers.convolutional.Conv2D object at 0x7f0a2509b110> True
<keras.layers.pooling.MaxPooling2D object at 0x7f0a250a3390> True
<keras.layers.convolutional.Conv2D object at 0x7f0a250a2510> True
<keras.layers.convolutional.Conv2D object at 0x7f0a25084110> True
<keras.layers.convolutional.Conv2D object at 0x7f0a25032fd0> True
<keras.layers.convolutional.Conv2D object at 0x7f0a2503af10> True
<keras.layers.pooling.MaxPooling2D object at 0x7f0a2502cc90> True
```

#Build CNN on the top of VGG19

```
# define sequential model
model = tf.keras.models.Sequential()

# Add the vgg convolutional base model
model.add(vgg_layers)

# add flatten layer
model.add(tf.keras.layers.Flatten())

# add dense layers with some dropout
model.add(tf.keras.layers.Dense(256, activation='relu'))
model.add(tf.keras.layers.Dropout(rate=0.3))
model.add(tf.keras.layers.Dense(256, activation='relu'))
model.add(tf.keras.layers.Dropout(rate=0.3))

# add output layer
model.add(tf.keras.layers.Dense(10, activation='softmax'))

# compile model
model.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=2e-5),
loss='sparse_categorical_crossentropy',
metrics=['accuracy'])

# view model layers
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 vgg19 (Functional)          (None, 1, 1, 512)         20024384

 flatten (Flatten)           (None, 512)               0

 dense (Dense)               (None, 256)               131328

 dropout (Dropout)           (None, 256)               0

 dense_1 (Dense)             (None, 256)               65792
```

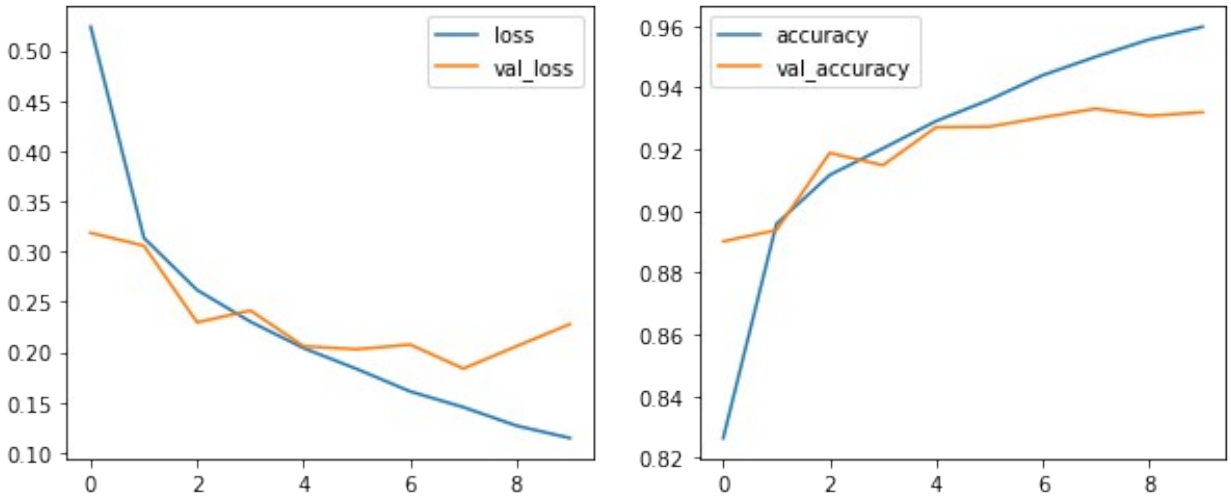
```
 dropout_1 (Dropout)          (None, 256)               0

 dense_2 (Dense)              (None, 10)                2570

=================================================================
Total params: 20,224,074
Trainable params: 20,224,074
Non-trainable params: 0
_________________________________________________________________
```

```
EPOCHS = 100
train_images_3ch_scaled = train_images_3ch / 255.
es_callback = tf.keras.callbacks.EarlyStopping(monitor='val_loss',
patience=2,
restore_best_weights=True,
verbose=1)

history = model.fit(train_images_3ch_scaled, train_labels,
batch_size=32,
callbacks=[es_callback],
validation_split=0.1, epochs=EPOCHS,
verbose=1)
```

```
Epoch 1/100
 869/1688 [==============>..............] - ETA: 56:29 - loss: 0.6488
- accuracy: 0.7827
```

#Accuracy graphs

```
import pandas as pd
fig, ax = plt.subplots(1, 2, figsize=(10, 4))

history_df = pd.DataFrame(history.history)
history_df[['loss', 'val_loss']].plot(kind='line', ax=ax[0])
history_df[['accuracy', 'val_accuracy']].plot(kind='line', ax=ax[1]);
```



#Test data accuracy

```
test_images_3ch_scaled = test_images_3ch / 255.
predictions = model.predict(test_images_3ch_scaled)
predictions[:5]
```

```
array([[8.2340867e-10, 2.8423059e-09, 2.0353642e-10, 5.0417581e-09,
        4.4183140e-10, 2.5759527e-07, 9.0209801e-10, 1.1363073e-05,
        1.3139400e-09, 9.9998832e-01],
       [2.4492384e-04, 5.2904752e-06, 9.9845862e-01, 2.3523331e-05,
        5.6046224e-04, 2.1584758e-05, 6.6686596e-04, 9.2018054e-06,
        6.5140521e-06, 2.9754356e-06],
       [1.3240979e-11, 1.0000000e+00, 2.7550812e-11, 1.3596733e-09,
        1.4097771e-11, 3.4155168e-11, 5.0390820e-11, 1.3885454e-11,
        3.7343105e-13, 1.0608974e-10],
       [9.7635571e-09, 9.9999964e-01, 1.6221936e-08, 3.1688836e-07,
        7.5511704e-09, 1.3278602e-08, 2.6905701e-08, 8.8272527e-09,
        5.8504795e-10, 3.3598564e-08],
       [4.9692589e-01, 7.8504533e-04, 1.2435036e-02, 5.7563242e-03,
        3.6659278e-03, 2.6308002e-03, 4.7291115e-01, 1.2741705e-03,
        2.1356090e-03, 1.4800023e-03]], dtype=float32)
```

```
prediction_labels = np.argmax(predictions, axis=1)
prediction_labels[:5]
```

```
array([9, 2, 1, 1, 0])
```

```
from sklearn.metrics import confusion_matrix, classification_report
import pandas as pd

print(classification_report(test_labels, prediction_labels,
target_names=class_names))
pd.DataFrame(confusion_matrix(test_labels, prediction_labels),
index=class_names, columns=class_names)
```

```
              precision    recall  f1-score   support

 T-shirt/top       0.87      0.89      0.88      1000
     Trouser       0.99      0.99      0.99      1000
    Pullover       0.88      0.92      0.90      1000
       Dress       0.92      0.93      0.93      1000
        Coat       0.87      0.91      0.89      1000
      Sandal       0.99      0.98      0.99      1000
       Shirt       0.84      0.74      0.79      1000
     Sneaker       0.98      0.97      0.97      1000
         Bag       0.99      0.99      0.99      1000
  Ankle boot       0.96      0.98      0.97      1000

    accuracy                           0.93     10000
   macro avg       0.93      0.93      0.93     10000
weighted avg       0.93      0.93      0.93     10000


              T-shirt/top  Trouser  Pullover  Dress  Coat  Sandal
Shirt  \
T-shirt/top           888        3        14     25     1       0
65
Trouser                 2      990         0      6     0       0
1
Pullover               14        1       915      7    33       0
30
Dress                  11        4        11    929    24       0
17
Coat                    3        1        42     14   909       0
30
Sandal                  0        0         0      0     0     983
0
Shirt                 100        2        54     26    72       0
742
Sneaker                 0        0         0      0     0       4
0
Bag                     1        0         1      1     1       1
0
Ankle boot              0        0         0      0     0       2
1

              Sneaker  Bag  Ankle boot
T-shirt/top         0    4           0
Trouser             0    1           0
Pullover            0    0           0
Dress               0    1           3
Coat                0    1           0
Sandal             11    0           6
Shirt               0    4           0
Sneaker           966    0          30
```

```
Bag                0  994           1
Ankle boot        13    0         984
```

```
print(test_labels[:100])
```

```
[9 2 1 1 6 1 4 6 5 7 4 5 7 3 4 1 2 4 8 0 2 5 7 9 1 4 6 0 9 3 8 8 3 3 8
0 7
 5 7 9 6 1 3 7 6 7 2 1 2 2 4 4 5 8 2 2 8 4 8 0 7 7 8 5 1 1 2 3 9 8 7 0
2 6
 2 3 1 2 8 4 1 8 5 9 5 0 3 2 0 6 5 3 6 7 1 8 0 1 4 2]
```

##F1 score is 0.93