```
%load_ext tensorboard
```

```
from tensorflow.keras.datasets import fashion_mnist
(X_train, Y_train), (X_test, Y_test) = fashion_mnist.load_data()
```

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

```
X_train.shape
```

```
(60000, 28, 28)
```

```
Y_train.shape
```

```
(60000,)
```

```
X_test.shape
```

```
(10000, 28, 28)
```

```
Y_test.shape
```

```
(10000,)
```

```
X_train = X_train.reshape((60000, 28, 28, 1))
X_train.shape
```

```
(60000, 28, 28, 1)
```

```
X_test = X_test.reshape((10000, 28, 28, 1))
X_test.shape
```

```
(10000, 28, 28, 1)
```

```
X_train = X_train.astype('float32') / 255
X_test = X_test.astype('float32') / 25
```

```
from tensorflow.keras.utils import to_categorical
y_train = to_categorical(Y_train)
y_train.shape
```

```
     (60000, 10)
```

```
y_train[0]
```

```
     array([0., 0., 0., 0., 0., 0., 0., 0., 0., 1.], dtype=float32)
```

```
y_test = to_categorical(Y_test)
y_test.shape
```

```
     (10000, 10)
```

```
from tensorflow.keras.models import Sequential
cnn = Sequential()
```

```
from tensorflow.keras.layers import Conv2D, Dense, Flatten, MaxPooling2D
```

```
cnn.add(Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(28, 28, 1)))
```

```
cnn.add(MaxPooling2D(pool_size=(2, 2)))
```

```
cnn.add(Conv2D(filters=128, kernel_size=(3, 3), activation='relu'))
cnn.add(MaxPooling2D(pool_size=(2, 2)))
```

```
cnn.add(Flatten())
```

```
cnn.add(Dense(units=128, activation='relu'))
```

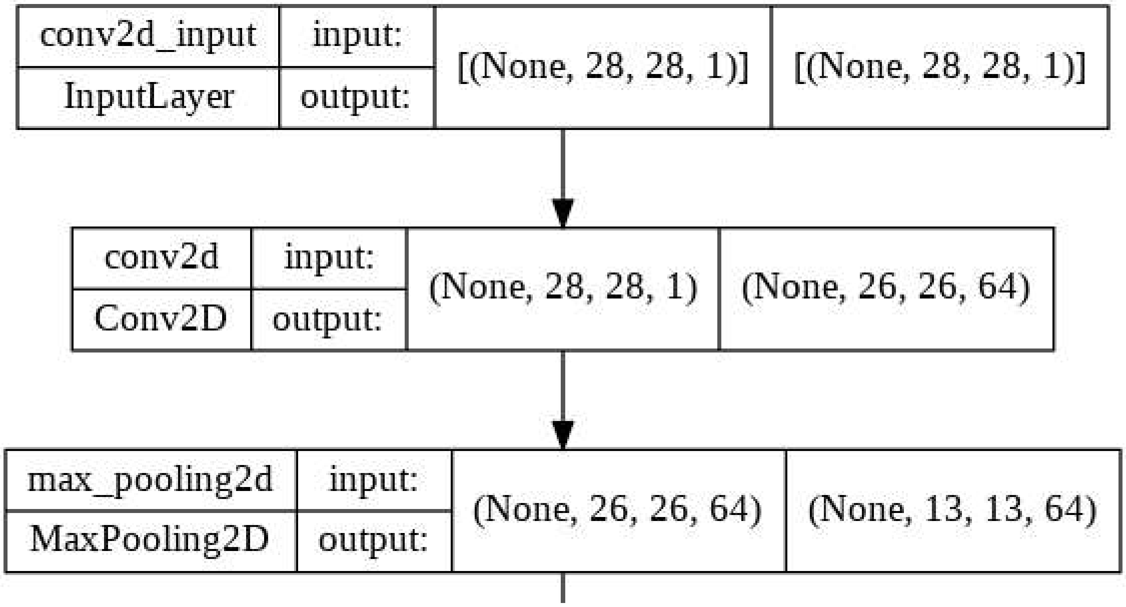
```
cnn.add(Dense(units=10, activation='softmax'))
```

```
cnn.summary()
```

```
     Model: "sequential"
     _________________________________________________________________
      Layer (type)                Output Shape              Param #
     =================================================================
      conv2d (Conv2D)             (None, 26, 26, 64)        640

      max_pooling2d (MaxPooling2D  (None, 13, 13, 64)       0
      )
```

```
 conv2d_1 (Conv2D)           (None, 11, 11, 128)       73856

 max_pooling2d_1 (MaxPooling  (None, 5, 5, 128)        0
 2D)

 flatten (Flatten)           (None, 3200)              0

 dense (Dense)               (None, 128)               409728

 dense_1 (Dense)             (None, 10)                1290

=================================================================
Total params: 485,514
Trainable params: 485,514
Non-trainable params: 0
_________________________________________________________________
```

```
from tensorflow.keras.utils import plot_model
from IPython.display import Image
plot_model(cnn, to_file='convnet.png', show_shapes=True, show_layer_names=True)
Image(filename='convnet.png')
```



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

```
cnn.fit(X_train, y_train, epochs=5, batch_size=64, validation_split=0.1)
```

```
Epoch 1/5
844/844 [==============================] - 116s 136ms/step - loss: 0.4576 - accuracy: 0
Epoch 2/5
844/844 [==============================] - 118s 140ms/step - loss: 0.3012 - accuracy: 0
Epoch 3/5
844/844 [==============================] - 114s 135ms/step - loss: 0.2520 - accuracy: 0
Epoch 4/5
844/844 [==============================] - 114s 135ms/step - loss: 0.2177 - accuracy: 0
Epoch 5/5
844/844 [==============================] - 114s 135ms/step - loss: 0.1922 - accuracy: 0
<keras.callbacks.History at 0x7f15df9df3d0>
```

```
#Here, the training time for this dataset was much faster at about 20ms/step when compared to
loss, accuracy = cnn.evaluate(X_test, y_test)
```

```
313/313 [==============================] - 6s 19ms/step - loss: 2.2157 - accuracy: 0.83(
```

```
loss
```

```
2.2156996726989746
```

```
#From this result, we can see that the model does not perform as well on the fashion-mnist da
#here the accuracy is 83% whereas there was an accuracy of 99% for the mnist dataset
accuracy
```

```
0.8307999968528748
```

```
predictions = cnn.predict(X_test)
```

```
y_test[0]
```

```
array([0., 0., 0., 0., 0., 0., 0., 0., 0., 1.], dtype=float32)
```

```
for index, probability in enumerate(predictions[0]):
  print(f'{index}: {probability:.10%}')
```

```
0: 0.0000000000%
1: 0.0000000000%
2: 0.0000000000%
3: 0.0000000000%
4: 0.0000000000%
5: 0.0000000000%
6: 0.0000000000%
7: 0.0000000000%
8: 0.0000000000%
9: 100.0000000000%
```

```
import numpy as np
images = X_test.reshape((10000, 28, 28))
incorrect_predictions = []

for i, (p, e) in enumerate(zip(predictions, y_test)):
    predicted, expected = np.argmax(p), np.argmax(e)

    if predicted != expected:
        incorrect_predictions.append(
            (i, images[i], predicted, expected))
```

```
len(incorrect_predictions)
```

```
1692
```

```
#16.4
#This model is to see what happens when you remove the first dense layer
cnn2 = Sequential()
cnn2.add(Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(28, 28, 1)))
cnn2.add(MaxPooling2D(pool_size=(2, 2)))
cnn2.add(Conv2D(filters=128, kernel_size=(3, 3), activation='relu'))
cnn2.add(MaxPooling2D(pool_size=(2, 2)))
cnn2.add(Flatten())
cnn2.add(Dense(units=10, activation='softmax'))
cnn2.summary()
```

```
Model: "sequential_1"
```

```
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_2 (Conv2D)           (None, 26, 26, 64)        640       
                                                                 
 max_pooling2d_2 (MaxPooling  (None, 13, 13, 64)       0         
 2D)                                                             
                                                                 
 conv2d_3 (Conv2D)           (None, 11, 11, 128)       73856     
                                                                 
 max_pooling2d_3 (MaxPooling  (None, 5, 5, 128)        0         
 2D)                                                             
                                                                 
 flatten_1 (Flatten)         (None, 3200)              0         
                                                                 
 dense_2 (Dense)             (None, 10)                32010     
                                                                 
=================================================================
Total params: 106,506
Trainable params: 106,506
Non-trainable params: 0
_________________________________________________________________
```

```
cnn2.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
```

```
cnn2.fit(X_train, y_train, epochs=5, batch_size=64, validation_split=0.1)
```

```
Epoch 1/5
844/844 [==============================] - 119s 141ms/step - loss: 0.4952 - accuracy: 0
Epoch 2/5
844/844 [==============================] - 118s 140ms/step - loss: 0.3332 - accuracy: 0
Epoch 3/5
844/844 [==============================] - 122s 145ms/step - loss: 0.2876 - accuracy: 0
Epoch 4/5
844/844 [==============================] - 121s 144ms/step - loss: 0.2579 - accuracy: 0
Epoch 5/5
844/844 [==============================] - 117s 138ms/step - loss: 0.2337 - accuracy: 0
<keras.callbacks.History at 0x7f15dddad0d0>
```

```
loss2, accuracy2 = cnn2.evaluate(X_test, y_test)
```

```
313/313 [==============================] - 6s 20ms/step - loss: 1.9805 - accuracy: 0.85
```

Here, the training time for this model was nearly the same speed at about 20ms/step when compared to the original model at 19ms/step

```
loss2
```

```
1.980485200881958
```

```
accuracy2
```

```
0.8549000024795532
```

Here the accuracy is 85.5% whereas there was an accuracy of 83% for the original model. Clearly, this model performed slightly better when compared to the original one.

```
#This model is to see what happens when you add another dense layer with 4096 neurons
cnn3 = Sequential()
cnn3.add(Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(28, 28, 1)))
cnn3.add(MaxPooling2D(pool_size=(2, 2)))
cnn3.add(Conv2D(filters=128, kernel_size=(3, 3), activation='relu'))
cnn3.add(MaxPooling2D(pool_size=(2, 2)))
cnn3.add(Flatten())
cnn3.add(Dense(units=4096, activation='relu'))
cnn3.add(Dense(units=128, activation='relu'))
cnn3.add(Dense(units=10, activation='softmax'))
cnn3.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_6 (Conv2D)           (None, 26, 26, 64)        640       
                                                                 
 max_pooling2d_6 (MaxPooling  (None, 13, 13, 64)       0         
 2D)                                                             
                                                                 
 conv2d_7 (Conv2D)           (None, 11, 11, 128)       73856     
                                                                 
 max_pooling2d_7 (MaxPooling  (None, 5, 5, 128)        0         
 2D)                                                             
                                                                 
 flatten_3 (Flatten)         (None, 3200)              0         
                                                                 
 dense_6 (Dense)             (None, 4096)              13111296  
                                                                 
 dense_7 (Dense)             (None, 128)               524416    
                                                                 
 dense_8 (Dense)             (None, 10)                1290      
                                                                 
=================================================================
Total params: 13,711,498
Trainable params: 13,711,498
Non-trainable params: 0
_________________________________________________________________
```

```
cnn3.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
```

```
cnn3.fit(X_train, y_train, epochs=5, batch_size=64, validation_split=0.1)
```

```
Epoch 1/5
844/844 [==============================] - 261s 308ms/step - loss: 0.4226 - accuracy: 0
Epoch 2/5
844/844 [==============================] - 256s 304ms/step - loss: 0.2738 - accuracy: 0
Epoch 3/5
844/844 [==============================] - 253s 300ms/step - loss: 0.2262 - accuracy: 0
Epoch 4/5
844/844 [==============================] - 252s 299ms/step - loss: 0.1892 - accuracy: 0
Epoch 5/5
844/844 [==============================] - 255s 302ms/step - loss: 0.1586 - accuracy: 0
<keras.callbacks.History at 0x7f15ddbef7d0>
```

```
loss3, accuracy3 = cnn3.evaluate(X_test, y_test)
```

```
313/313 [==============================] - 13s 43ms/step - loss: 2.3544 - accuracy: 0.84
```

Here, the training time for this model was slower at about 43ms/step when compared to the original model at 19ms/step

```
loss3
```

```
2.3544256687164307
```

```
accuracy3
```

```
0.8416000008583069
```

Here the accuracy is 84% whereas there was an accuracy of 83% for the original model. Clearly, this model performed slightly better when compared to the original one.

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