In [3]:
```
import tensorflow as tf
from tensorflow import keras
import matplotlib as mpl
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
tf.__version__
```

Out[3]:
```
'2.7.0'
```

In [2]:
```
keras.__version__
```

Out[2]:
```
'2.7.0'
```

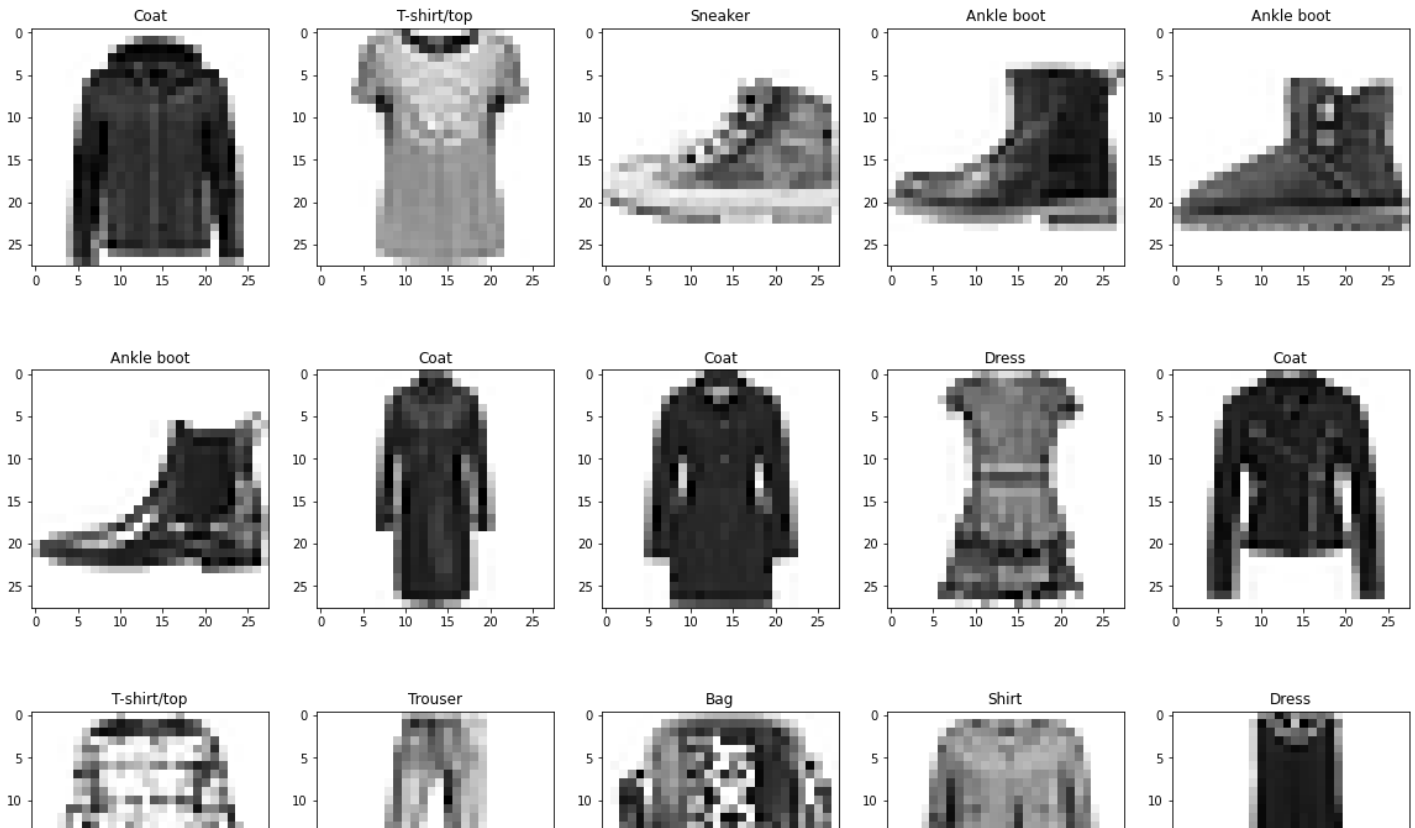
In [140…
```
fashion_mnist = keras.datasets.fashion_mnist
(X_train_full, y_train_full), (X_test, y_test) = fashion_mnist.load_data()
```

In [141…
```
X_valid, X_train,X_test = X_train_full[:5000] / 255.0, X_train_full[5000:] / 255.0, X_test
y_valid, y_train = y_train_full[:5000], y_train_full[5000:]
```

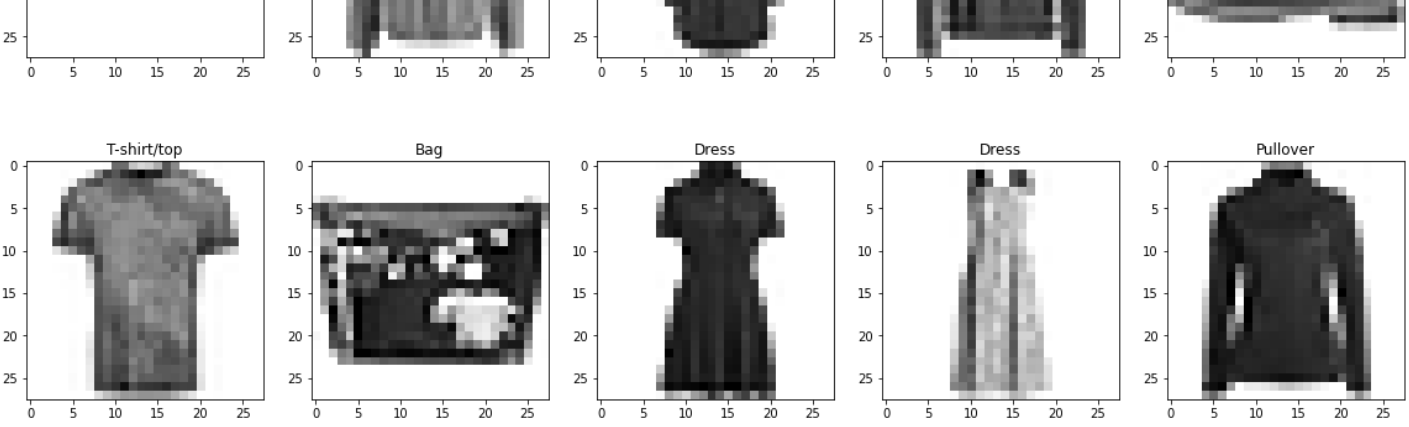
In [142…
```
class_names = ["T-shirt/top", "Trouser", "Pullover", "Dress", "Coat","Sandal", "Shirt", "S
```

In [143…
```
items_size=50
cols=5
fig, ax = plt.subplots(items_size//cols,cols)
fig.set_size_inches(20, 50)

for i in range(items_size):
    ax[i//cols,i%cols].imshow(X_train[i],cmap='binary')
    ax[i//cols,i%cols].set_title(class_names[y_train[i]])
```




Shirt
Coat
Dress
Pullover
Bag
Sneaker
Dress
Coat
Sneaker
Trouser
Dress
Coat
Pullover
T-shirt/top
Bag
Sandal
Sandal
Ankle boot
Trouser
Sandal
Dress
Sandal
Ankle boot
T-shirt/top
Dress
Ankle boot
Shirt
Coat
Pullover
Ankle boot



In [144…]:
```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(300, activation="relu"),
    keras.layers.Dense(100, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
```

In [28]:
```
model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 flatten_2 (Flatten)         (None, 784)               0

 dense_6 (Dense)             (None, 300)               235500

 dense_7 (Dense)             (None, 100)               30100

 dense_8 (Dense)             (None, 10)                1010

=================================================================
Total params: 266,610
Trainable params: 266,610
Non-trainable params: 0
_________________________________________________________________
```

In [29]:
```
model.layers
```

Out[29]:
```
[<keras.layers.core.flatten.Flatten at 0x7f03b6b4d3d0>,
 <keras.layers.core.dense.Dense at 0x7f03c0dabdf0>,
 <keras.layers.core.dense.Dense at 0x7f03c0dabd00>,
 <keras.layers.core.dense.Dense at 0x7f03c16186a0>]
```

In [31]:
```
weights,biases = model.layers[1].get_weights()
```

In [34]:
```
weights.shape
```

Out[34]:
```
(784, 300)
```

In [35]:
```
weights
```

Out[35]:
```
array([[ 0.00653134, -0.01500392, -0.01274717, ..., -0.07062194,
        -0.01046152,  0.03224412],
       [-0.00821073, -0.04175482, -0.04600877, ..., -0.04691035,
```

```
          -0.036466  , -0.06062309],
        [ 0.05702101,  0.06753059,  0.00880871, ..., -0.0041343 ,
          0.05217037,  0.06015237],
        ...,
        [-0.00702417,  0.07321852,  0.01344192, ..., -0.03066761,
          0.0401414 , -0.03592064],
        [-0.06526814, -0.0368433 ,  0.05044339, ...,  0.04609454,
          0.05443448, -0.03585379],
        [ 0.03443138, -0.01825057, -0.02389743, ...,  0.01357771,
         -0.02014548,  0.03946279]], dtype=float32)
```

In [36]:

```python
print(biases.shape)
biases
```

```
(300,)
```

Out[36]:

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

In [145…

```python
model.compile(loss="sparse_categorical_crossentropy",
              optimizer="sgd",
              metrics=["accuracy"])
```

In [48]:

```python
history = model.fit(X_train,y_train,epochs=30,validation_data=(X_valid,y_valid))
```

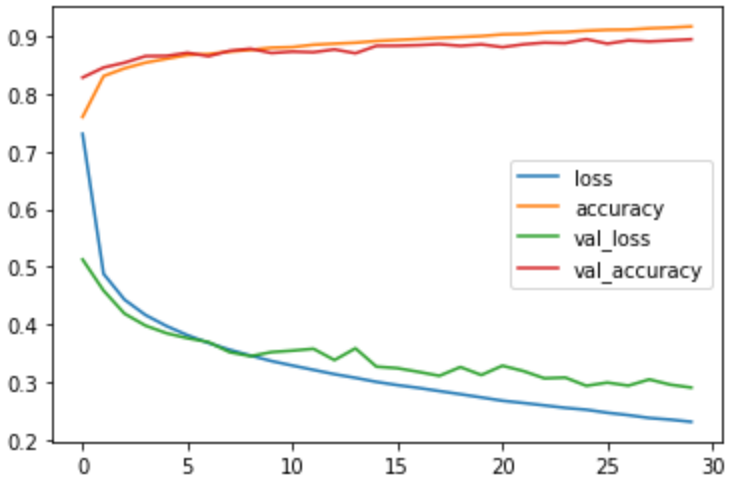
```
2022-01-16 12:59:33.879457: W tensorflow/core/framework/cpu_allocator_impl.cc:82] Allocati
on of 172480000 exceeds 10% of free system memory.
Epoch 1/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.7306 - accuracy: 0.7599
- val_loss: 0.5126 - val_accuracy: 0.8284
Epoch 2/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.4877 - accuracy: 0.8310
- val_loss: 0.4586 - val_accuracy: 0.8458
Epoch 3/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.4429 - accuracy: 0.8444
- val_loss: 0.4186 - val_accuracy: 0.8542
Epoch 4/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.4162 - accuracy: 0.8543
- val_loss: 0.3978 - val_accuracy: 0.8656
Epoch 5/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3971 - accuracy: 0.8609
- val_loss: 0.3846 - val_accuracy: 0.8660
Epoch 6/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3812 - accuracy: 0.8675
- val_loss: 0.3760 - val_accuracy: 0.8714
Epoch 7/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3677 - accuracy: 0.8691
```

```
- val_loss: 0.3693 - val_accuracy: 0.8654
Epoch 8/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3560 - accuracy: 0.8735
- val_loss: 0.3518 - val_accuracy: 0.8748
Epoch 9/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3459 - accuracy: 0.8764
- val_loss: 0.3448 - val_accuracy: 0.8784
Epoch 10/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3363 - accuracy: 0.8802
- val_loss: 0.3518 - val_accuracy: 0.8710
Epoch 11/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3285 - accuracy: 0.8812
- val_loss: 0.3544 - val_accuracy: 0.8734
Epoch 12/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3210 - accuracy: 0.8854
- val_loss: 0.3576 - val_accuracy: 0.8724
Epoch 13/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.3135 - accuracy: 0.8872
- val_loss: 0.3380 - val_accuracy: 0.8772
Epoch 14/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.3071 - accuracy: 0.8889
- val_loss: 0.3584 - val_accuracy: 0.8706
Epoch 15/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3002 - accuracy: 0.8919
- val_loss: 0.3266 - val_accuracy: 0.8834
Epoch 16/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2945 - accuracy: 0.8936
- val_loss: 0.3239 - val_accuracy: 0.8836
Epoch 17/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2897 - accuracy: 0.8953
- val_loss: 0.3176 - val_accuracy: 0.8846
Epoch 18/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2842 - accuracy: 0.8972
- val_loss: 0.3107 - val_accuracy: 0.8864
Epoch 19/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2788 - accuracy: 0.8986
- val_loss: 0.3259 - val_accuracy: 0.8834
Epoch 20/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2732 - accuracy: 0.9004
- val_loss: 0.3120 - val_accuracy: 0.8860
Epoch 21/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2675 - accuracy: 0.9033
- val_loss: 0.3282 - val_accuracy: 0.8812
Epoch 22/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2636 - accuracy: 0.9041
- val_loss: 0.3190 - val_accuracy: 0.8860
Epoch 23/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2594 - accuracy: 0.9065
- val_loss: 0.3064 - val_accuracy: 0.8890
Epoch 24/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2550 - accuracy: 0.9075
- val_loss: 0.3076 - val_accuracy: 0.8882
Epoch 25/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2518 - accuracy: 0.9097
- val_loss: 0.2934 - val_accuracy: 0.8950
Epoch 26/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2466 - accuracy: 0.9112
- val_loss: 0.2989 - val_accuracy: 0.8872
Epoch 27/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2425 - accuracy: 0.9116
- val_loss: 0.2936 - val_accuracy: 0.8928
Epoch 28/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2375 - accuracy: 0.9138
- val_loss: 0.3044 - val_accuracy: 0.8910
Epoch 29/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2346 - accuracy: 0.9151
```

```
- val_loss: 0.2953 - val_accuracy: 0.8928
Epoch 30/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2308 - accuracy: 0.9171
- val_loss: 0.2903 - val_accuracy: 0.8948
```

In [49]:
```
pd.DataFrame(history.history).plot()
```

Out[49]:
```
<AxesSubplot:>
```



In [50]:
```
model.evaluate(X_test,y_test)
```

```
313/313 [==============================] - 1s 2ms/step - loss: 61.2432 - accuracy: 0.8506
```

Out[50]:
```
[61.24318313598633, 0.850600004196167]
```

In [51]:
```
history = model.fit(X_train,y_train,epochs=30,validation_data=(X_valid,y_valid))
```

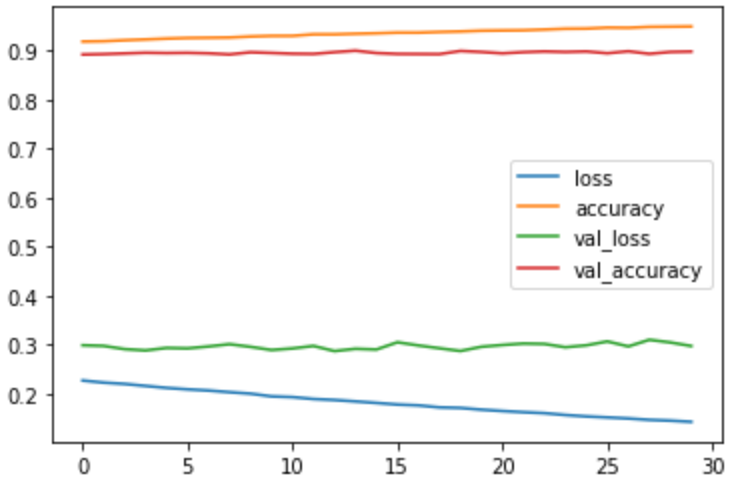
```
Epoch 1/30
  60/1719 [>.............................] - ETA: 4s - loss: 0.2245 - accuracy: 0.9208
2022-01-16 13:04:34.127316: W tensorflow/core/framework/cpu_allocator_impl.cc:82] Allocati
on of 172480000 exceeds 10% of free system memory.
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2271 - accuracy: 0.9180
- val_loss: 0.2990 - val_accuracy: 0.8916
Epoch 2/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2229 - accuracy: 0.9187
- val_loss: 0.2977 - val_accuracy: 0.8924
Epoch 3/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2202 - accuracy: 0.9207
- val_loss: 0.2911 - val_accuracy: 0.8938
Epoch 4/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2161 - accuracy: 0.9223
- val_loss: 0.2885 - val_accuracy: 0.8952
Epoch 5/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2120 - accuracy: 0.9240
- val_loss: 0.2935 - val_accuracy: 0.8946
Epoch 6/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2091 - accuracy: 0.9253
- val_loss: 0.2926 - val_accuracy: 0.8950
Epoch 7/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2067 - accuracy: 0.9257
- val_loss: 0.2965 - val_accuracy: 0.8940
Epoch 8/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2033 - accuracy: 0.9263
- val_loss: 0.3012 - val_accuracy: 0.8918
Epoch 9/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2003 - accuracy: 0.9283
- val_loss: 0.2958 - val_accuracy: 0.8962
```

```
Epoch 10/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1948 - accuracy: 0.9295
- val_loss: 0.2893 - val_accuracy: 0.8948
Epoch 11/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.1933 - accuracy: 0.9296
- val_loss: 0.2925 - val_accuracy: 0.8932
Epoch 12/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1894 - accuracy: 0.9328
- val_loss: 0.2976 - val_accuracy: 0.8928
Epoch 13/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1874 - accuracy: 0.9327
- val_loss: 0.2871 - val_accuracy: 0.8964
Epoch 14/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.1845 - accuracy: 0.9339
- val_loss: 0.2918 - val_accuracy: 0.8994
Epoch 15/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1814 - accuracy: 0.9349
- val_loss: 0.2903 - val_accuracy: 0.8946
Epoch 16/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1781 - accuracy: 0.9362
- val_loss: 0.3051 - val_accuracy: 0.8928
Epoch 17/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1764 - accuracy: 0.9362
- val_loss: 0.2986 - val_accuracy: 0.8926
Epoch 18/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1723 - accuracy: 0.9375
- val_loss: 0.2928 - val_accuracy: 0.8924
Epoch 19/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1712 - accuracy: 0.9386
- val_loss: 0.2872 - val_accuracy: 0.8988
Epoch 20/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1677 - accuracy: 0.9401
- val_loss: 0.2959 - val_accuracy: 0.8968
Epoch 21/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.1649 - accuracy: 0.9406
- val_loss: 0.2995 - val_accuracy: 0.8940
Epoch 22/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1625 - accuracy: 0.9410
- val_loss: 0.3024 - val_accuracy: 0.8964
Epoch 23/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1606 - accuracy: 0.9425
- val_loss: 0.3016 - val_accuracy: 0.8978
Epoch 24/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.1568 - accuracy: 0.9441
- val_loss: 0.2950 - val_accuracy: 0.8968
Epoch 25/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1539 - accuracy: 0.9444
- val_loss: 0.2988 - val_accuracy: 0.8978
Epoch 26/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1519 - accuracy: 0.9464
- val_loss: 0.3068 - val_accuracy: 0.8942
Epoch 27/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1497 - accuracy: 0.9460
- val_loss: 0.2966 - val_accuracy: 0.8982
Epoch 28/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1469 - accuracy: 0.9479
- val_loss: 0.3101 - val_accuracy: 0.8930
Epoch 29/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1453 - accuracy: 0.9483
- val_loss: 0.3047 - val_accuracy: 0.8968
Epoch 30/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.1429 - accuracy: 0.9487
- val_loss: 0.2974 - val_accuracy: 0.8976
```

In [52]:

```
pd.DataFrame(history.history).plot()
```

Out[52]:
```
<AxesSubplot:>
```

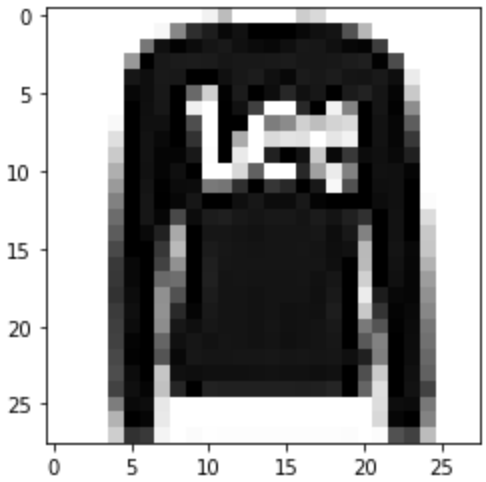


In [53]:
```
model.evaluate(X_test,y_test)
```

```
313/313 [==============================] - 1s 2ms/step - loss: 77.4195 - accuracy: 0.8445
```
Out[53]:
```
[77.41948699951172, 0.8445000052452087]
```

In [68]:
```
plt.imshow(X_test[1],cmap='binary')
```

Out[68]:
```
<matplotlib.image.AxesImage at 0x7f03bc97fd60>
```



In [96]:
```
model.predict(np.array([X_test[1]]))
```

Out[96]:
```
array([[1.08464644e-06, 1.78268240e-12, 9.99689460e-01, 1.52158869e-10,
        2.96724320e-04, 5.48206432e-14, 1.27099875e-05, 1.69373391e-12,
        2.20151744e-11, 5.77150225e-14]], dtype=float32)
```

In [99]:
```
y_pred=model.predict(X_test[:3])
y_pred
```

Out[99]:
```
array([[7.4789234e-08, 5.1169327e-08, 3.8751185e-08, 3.3776138e-07,
        3.0989508e-08, 9.5724936e-05, 9.6006056e-07, 1.8076556e-04,
        1.9559907e-06, 9.9972004e-01],
       [1.0846506e-06, 1.7826892e-12, 9.9968946e-01, 1.5215916e-10,
        2.9672575e-04, 5.4820748e-14, 1.2710048e-05, 1.6937372e-12,
        2.2015259e-11, 5.7715239e-14],
       [6.1468306e-08, 9.9999976e-01, 2.0466534e-10, 4.7997983e-09,
```

```
       1.4440363e-07, 9.3993898e-14, 2.4744807e-11, 1.1390221e-12,
       4.4947008e-11, 5.4884614e-15]], dtype=float32)
```

In [110…

```
predicted_classes=[]
for pred in y_pred:
    predicted_classes.append(pred.argmax())
print(predicted_classes)
pred_names=np.array(class_names)[predicted_classes]
pred_names
```

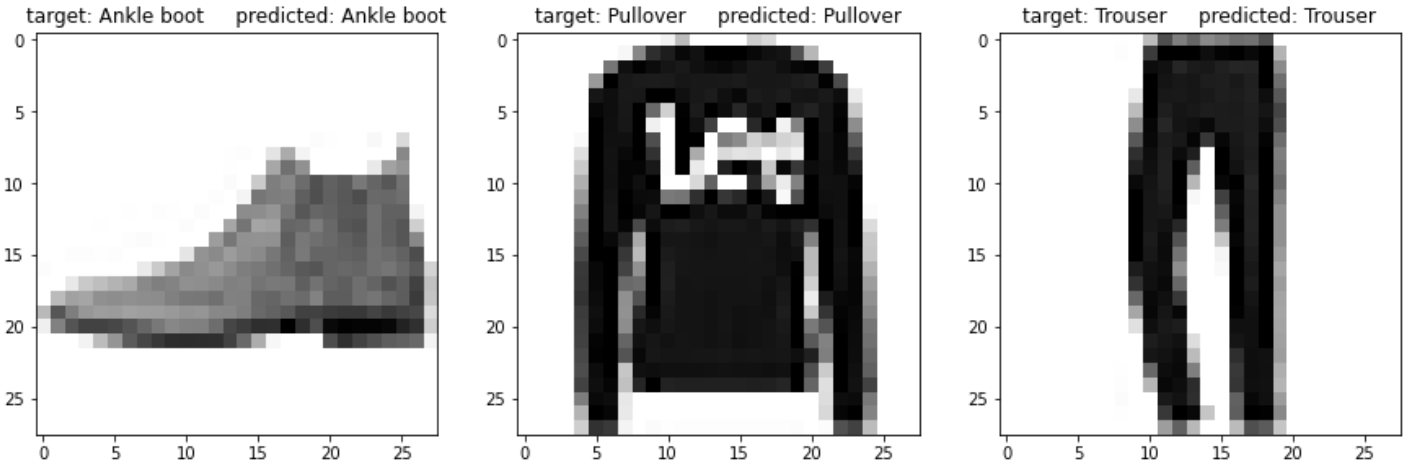
```
[9, 2, 1]
array(['Ankle boot', 'Pullover', 'Trouser'], dtype='<U11')
```

Out[110…

In [120…

```
fig, ax = plt.subplots(1,3)
fig.set_size_inches(15, 5)

for i in range(3):
    ax[i].imshow(X_test[i],cmap='binary')
    ax[i].set_title('target: '+str(class_names[y_test[i]])+'     predicted: '+pred_names[i
```



Regression

In [121…

```
from sklearn.datasets import fetch_california_housing
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
housing = fetch_california_housing()
X_train_full, X_test, y_train_full, y_test = train_test_split(housing.data, housing.target
X_train, X_valid, y_train, y_valid = train_test_split( X_train_full, y_train_full)
scaler = StandardScaler()
X_train = scaler.fit_transform(X_train)
X_valid = scaler.transform(X_valid)
X_test = scaler.transform(X_test)
```

In [122…

```
model = keras.models.Sequential([
    keras.layers.Dense(30, activation="relu", input_shape=X_train.shape[1:]),
    keras.layers.Dense(1)
])
model.compile(loss="mean_squared_error", optimizer="sgd")
history = model.fit(X_train, y_train, epochs=20,
                    validation_data=(X_valid, y_valid))
mse_test = model.evaluate(X_test, y_test)
X_new = X_test[:3] # pretend these are new instances
y_pred = model.predict(X_new)
```

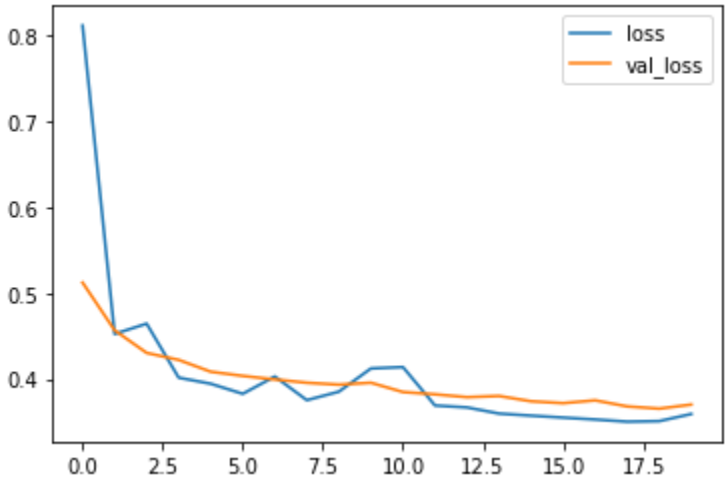
```
Epoch 1/20
363/363 [==============================] - 1s 1ms/step - loss: 0.8118 - val_loss: 0.5124
Epoch 2/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4525 - val_loss: 0.4568
Epoch 3/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4645 - val_loss: 0.4304
Epoch 4/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4016 - val_loss: 0.4223
Epoch 5/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3945 - val_loss: 0.4085
Epoch 6/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3828 - val_loss: 0.4037
Epoch 7/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4029 - val_loss: 0.3995
Epoch 8/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3754 - val_loss: 0.3957
Epoch 9/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3853 - val_loss: 0.3935
Epoch 10/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4123 - val_loss: 0.3957
Epoch 11/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4139 - val_loss: 0.3848
Epoch 12/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3692 - val_loss: 0.3822
Epoch 13/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3669 - val_loss: 0.3789
Epoch 14/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3598 - val_loss: 0.3803
Epoch 15/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3574 - val_loss: 0.3741
Epoch 16/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3551 - val_loss: 0.3719
Epoch 17/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3529 - val_loss: 0.3752
Epoch 18/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3503 - val_loss: 0.3681
Epoch 19/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3510 - val_loss: 0.3655
Epoch 20/20
363/363 [==============================] - 0s 1ms/step - loss: 0.3593 - val_loss: 0.3703
162/162 [==============================] - 0s 746us/step - loss: 0.3737
```

In [123…

```
pd.DataFrame(history.history).plot()
```

Out[123…

```
<AxesSubplot:>
```



In [127…

```
X_train[1].shape
```

Out[127… (8,)

functional API

Wide & Deep neural network

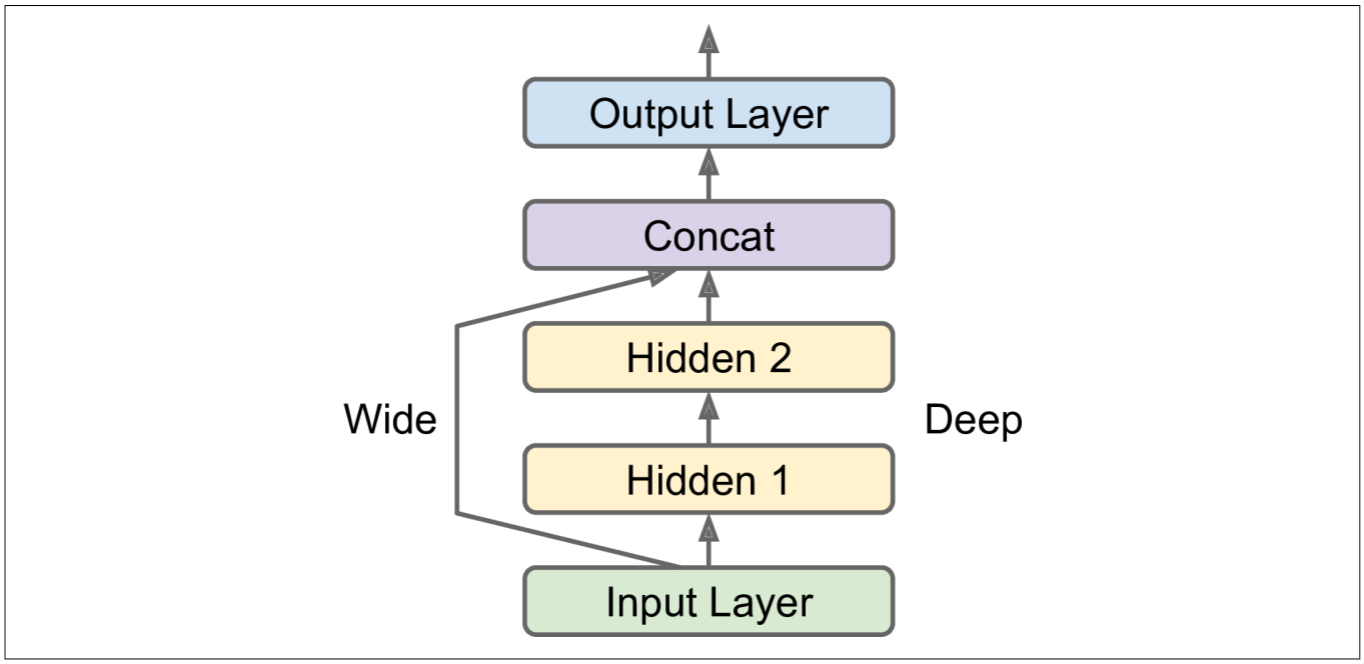


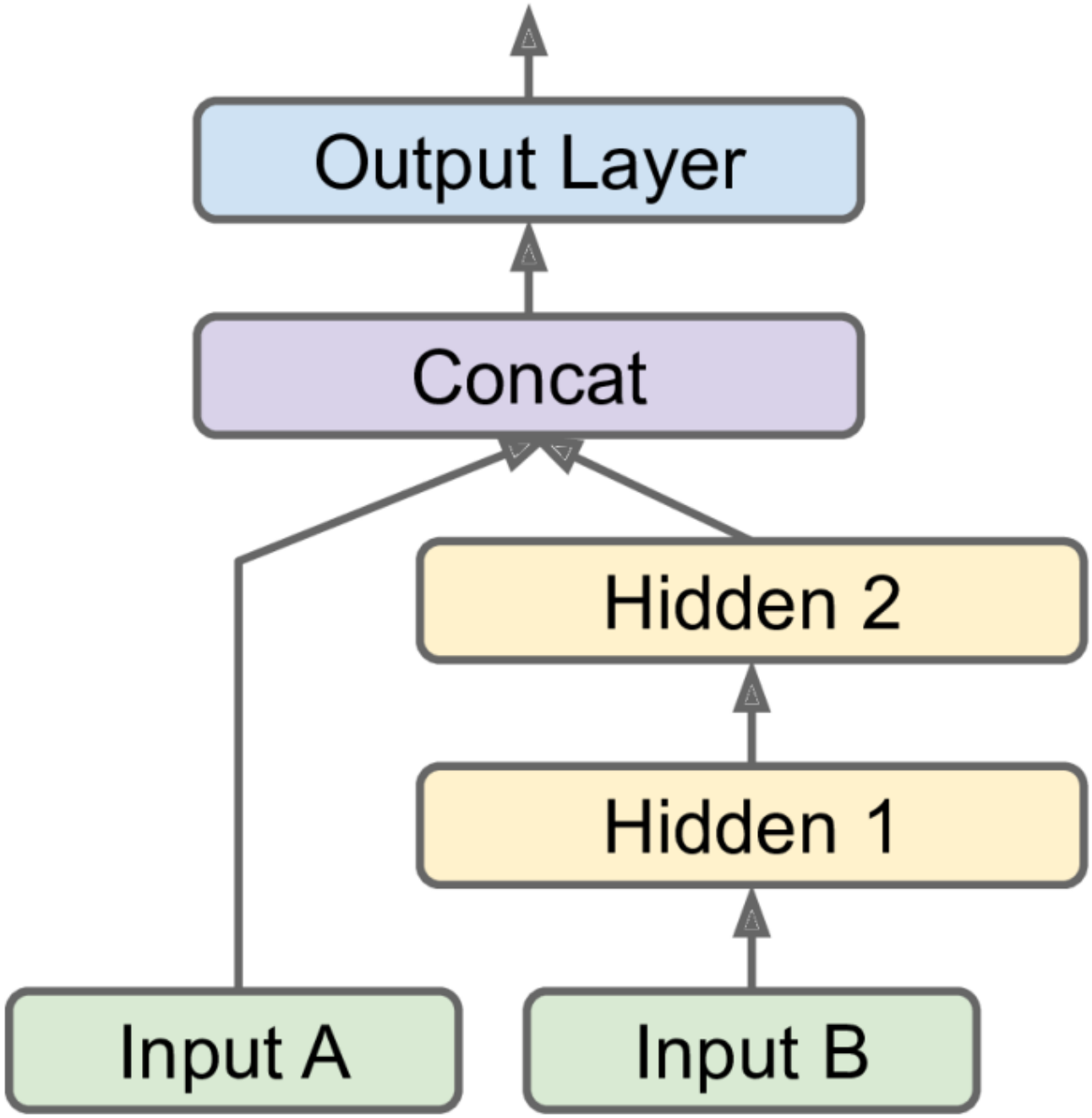
Figure 10-14. Wide & Deep neural network

This architecture makes it possible for the neural network to learn both deep patterns (using the deep path) and simple rules (through the short path). In contrast, a regular MLP forces all the data to flow through the full stack of layers;

In [131…

```
input_ = keras.layers.Input(shape=X_train.shape[1:])
hidden1 = keras.layers.Dense(30, activation="relu")(input_)
hidden2 = keras.layers.Dense(30, activation="relu")(hidden1)
concat = keras.layers.Concatenate()([input_, hidden2])
output = keras.layers.Dense(1)(concat)
model = keras.Model(inputs=[input_], outputs=[output])
```

multiple inputs



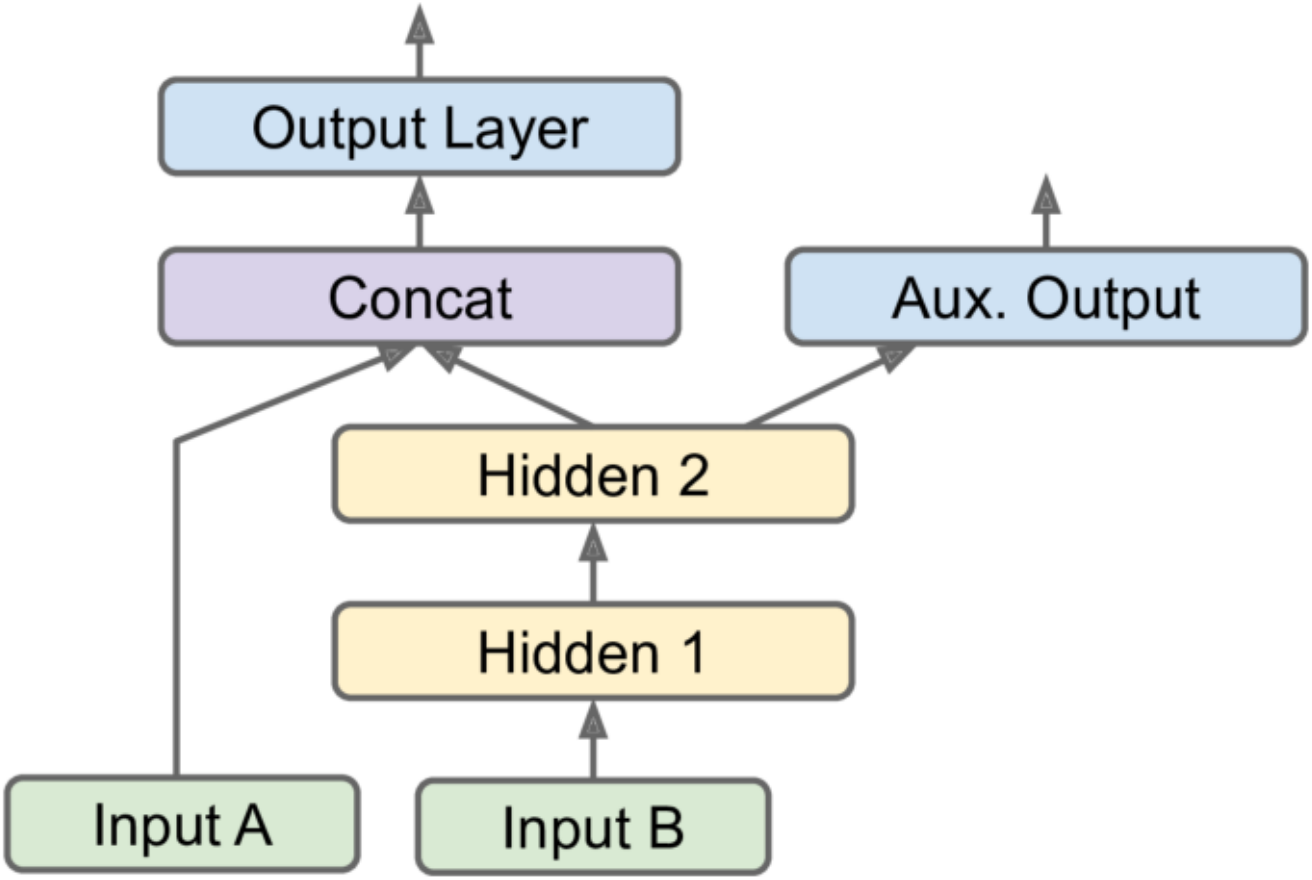
In [132…

```
input_A = keras.layers.Input(shape=[5], name="wide_input")
input_B = keras.layers.Input(shape=[6], name="deep_input")
hidden1 = keras.layers.Dense(30, activation="relu")(input_B)
hidden2 = keras.layers.Dense(30, activation="relu")(hidden1)
concat = keras.layers.concatenate([input_A, hidden2])
output = keras.layers.Dense(1, name="output")(concat)
model = keras.Model(inputs=[input_A, input_B], outputs=[output])
##
model.compile(loss="mse", optimizer=keras.optimizers.SGD(lr=1e-3))
X_train_A, X_train_B = X_train[:, :5], X_train[:, 2:]
X_valid_A, X_valid_B = X_valid[:, :5], X_valid[:, 2:]
X_test_A, X_test_B = X_test[:, :5], X_test[:, 2:]
X_new_A, X_new_B = X_test_A[:3], X_test_B[:3]
history = model.fit((X_train_A, X_train_B), y_train, epochs=20,validation_data=((X_valid_A
mse_test = model.evaluate((X_test_A, X_test_B), y_test)
y_pred = model.predict((X_new_A, X_new_B))
```

```
/home/bb/.local/lib/python3.9/site-packages/keras/optimizer_v2/gradient_descent.py:102: Us
erWarning: The `lr` argument is deprecated, use `learning_rate` instead.
  super(SGD, self).__init__(name, **kwargs)
```

```
Epoch 1/20
363/363 [==============================] - 1s 2ms/step - loss: 1.8215 - val_loss: 0.8419
Epoch 2/20
363/363 [==============================] - 1s 1ms/step - loss: 0.6659 - val_loss: 0.6492
Epoch 3/20
363/363 [==============================] - 0s 1ms/step - loss: 0.5942 - val_loss: 0.5999
Epoch 4/20
363/363 [==============================] - 0s 1ms/step - loss: 0.5573 - val_loss: 0.5673
Epoch 5/20
363/363 [==============================] - 0s 1ms/step - loss: 0.5297 - val_loss: 0.5430
Epoch 6/20
363/363 [==============================] - 0s 1ms/step - loss: 0.5097 - val_loss: 0.5241
Epoch 7/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4929 - val_loss: 0.5089
Epoch 8/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4792 - val_loss: 0.4965
Epoch 9/20
363/363 [==============================] - 1s 2ms/step - loss: 0.4683 - val_loss: 0.4926
Epoch 10/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4564 - val_loss: 0.4780
Epoch 11/20
363/363 [==============================] - 1s 1ms/step - loss: 0.4545 - val_loss: 0.4715
Epoch 12/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4456 - val_loss: 0.4705
Epoch 13/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4426 - val_loss: 0.4613
Epoch 14/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4363 - val_loss: 0.4590
Epoch 15/20
363/363 [==============================] - 1s 1ms/step - loss: 0.4327 - val_loss: 0.4543
Epoch 16/20
363/363 [==============================] - 1s 1ms/step - loss: 0.4280 - val_loss: 0.4485
Epoch 17/20
363/363 [==============================] - 1s 1ms/step - loss: 0.4247 - val_loss: 0.4506
Epoch 18/20
363/363 [==============================] - 0s 1ms/step - loss: 0.4244 - val_loss: 0.4436
Epoch 19/20
363/363 [==============================] - 1s 1ms/step - loss: 0.4199 - val_loss: 0.4398
Epoch 20/20
363/363 [==============================] - 1s 2ms/step - loss: 0.4174 - val_loss: 0.4387
162/162 [==============================] - 0s 860us/step - loss: 0.4452
```

auxiliary output (can be used for regularization)



In [ ]:
```
#[...] Same as above, up to the main output layer
output = keras.layers.Dense(1, name="main_output")(concat)
aux_output = keras.layers.Dense(1, name="aux_output")(hidden2)
model = keras.Model(inputs=[input_A, input_B], outputs=[output, aux_output])
# because we care more about the main output
model.compile(loss=["mse", "mse"], loss_weights=[0.9, 0.1], optimizer="sgd")
```

Subclassing API

In [ ]:
```
class WideAndDeepModel(keras.Model):
    def __init__(self, units=30, activation="relu", **kwargs):
        super().__init__(**kwargs) # handles standard args (e.g., name)
        self.hidden1 = keras.layers.Dense(units, activation=activation)
        self.hidden2 = keras.layers.Dense(units, activation=activation)
        self.main_output = keras.layers.Dense(1)
        self.aux_output = keras.layers.Dense(1)
    def call(self, inputs):
        input_A, input_B = inputs
        hidden1 = self.hidden1(input_B)
        hidden2 = self.hidden2(hidden1)
        concat = keras.layers.concatenate([input_A, hidden2])
        main_output = self.main_output(concat)
        aux_output = self.aux_output(hidden2)
        return main_output, aux_output
model = WideAndDeepModel()
```

for more flexibility we can use subclass api because we can use conditions and loops in the call function

Saving the model (only works for functional and sequential API)

In [ ]:
```
model = keras.models.Sequential([...]) # or keras.Model([...])
model.compile([...])
```

```
model.fit([...])
model.save("my_keras_model.h5")

##  loading
model = keras.models.load_model("my_keras_model.h5")
```

save one at each epoch

In [ ]:

```
checkpoint_cb = keras.callbacks.ModelCheckpoint("my_keras_model.h5",
                                                save_best_only=True)
history = model.fit(X_train, y_train, epochs=10,
                    validation_data=(X_valid, y_valid),
                    callbacks=[checkpoint_cb])
model = keras.models.load_model("my_keras_model.h5") # roll back to best model
```

stop training when the model does not get better after 10 epochs

In [ ]:

```
early_stopping_cb = keras.callbacks.EarlyStopping(patience=10,
                                                  restore_best_weights=True)
history = model.fit(X_train, y_train, epochs=100,
                    validation_data=(X_valid, y_valid),
                    callbacks=[checkpoint_cb, early_stopping_cb])
```

In [11]:

```
import os
root_logdir = os.path.join(os.curdir, "my_logs")
def get_run_logdir():
    import time
    run_id = time.strftime("run_%Y_%m_%d-%H_%M_%S")
    return os.path.join(root_logdir, run_id)
```

In [146…

```
run_logdir = get_run_logdir() # e.g., './my_logs/run_2019_06_07-15_15_22'
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=30,
                    validation_data=(X_valid, y_valid),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.7246 - accuracy: 0.7643
- val_loss: 0.5243 - val_accuracy: 0.8178
Epoch 2/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.4879 - accuracy: 0.8310
- val_loss: 0.4616 - val_accuracy: 0.8396
Epoch 3/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.4411 - accuracy: 0.8453
- val_loss: 0.4454 - val_accuracy: 0.8410
Epoch 4/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.4136 - accuracy: 0.8553
- val_loss: 0.4039 - val_accuracy: 0.8610
Epoch 5/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.3927 - accuracy: 0.8624
- val_loss: 0.3893 - val_accuracy: 0.8640
Epoch 6/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.3765 - accuracy: 0.8671
- val_loss: 0.3767 - val_accuracy: 0.8708
Epoch 7/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3648 - accuracy: 0.8715
- val_loss: 0.3754 - val_accuracy: 0.8670
Epoch 8/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3518 - accuracy: 0.8754
- val_loss: 0.3500 - val_accuracy: 0.8766
```

```
Epoch 9/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3418 - accuracy: 0.8792
- val_loss: 0.3425 - val_accuracy: 0.8814
Epoch 10/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3333 - accuracy: 0.8818
- val_loss: 0.3467 - val_accuracy: 0.8772
Epoch 11/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.3242 - accuracy: 0.8832
- val_loss: 0.3466 - val_accuracy: 0.8796
Epoch 12/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3169 - accuracy: 0.8863
- val_loss: 0.3602 - val_accuracy: 0.8720
Epoch 13/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.3095 - accuracy: 0.8892
- val_loss: 0.3290 - val_accuracy: 0.8832
Epoch 14/30
1719/1719 [==============================] - 6s 4ms/step - loss: 0.3035 - accuracy: 0.8905
- val_loss: 0.3410 - val_accuracy: 0.8786
Epoch 15/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2974 - accuracy: 0.8940
- val_loss: 0.3420 - val_accuracy: 0.8792
Epoch 16/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2907 - accuracy: 0.8967
- val_loss: 0.3316 - val_accuracy: 0.8838
Epoch 17/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2853 - accuracy: 0.8983
- val_loss: 0.3376 - val_accuracy: 0.8798
Epoch 18/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2799 - accuracy: 0.8998
- val_loss: 0.3101 - val_accuracy: 0.8904
Epoch 19/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2742 - accuracy: 0.9012
- val_loss: 0.3373 - val_accuracy: 0.8758
Epoch 20/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2698 - accuracy: 0.9034
- val_loss: 0.3138 - val_accuracy: 0.8864
Epoch 21/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2638 - accuracy: 0.9060
- val_loss: 0.3120 - val_accuracy: 0.8846
Epoch 22/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2597 - accuracy: 0.9060
- val_loss: 0.3203 - val_accuracy: 0.8890
Epoch 23/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2555 - accuracy: 0.9077
- val_loss: 0.3176 - val_accuracy: 0.8844
Epoch 24/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2499 - accuracy: 0.9096
- val_loss: 0.3123 - val_accuracy: 0.8876
Epoch 25/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2467 - accuracy: 0.9111
- val_loss: 0.3055 - val_accuracy: 0.8914
Epoch 26/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2425 - accuracy: 0.9134
- val_loss: 0.3083 - val_accuracy: 0.8886
Epoch 27/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2390 - accuracy: 0.9130
- val_loss: 0.2979 - val_accuracy: 0.8928
Epoch 28/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2343 - accuracy: 0.9150
- val_loss: 0.3004 - val_accuracy: 0.8946
Epoch 29/30
1719/1719 [==============================] - 6s 3ms/step - loss: 0.2308 - accuracy: 0.9170
- val_loss: 0.2949 - val_accuracy: 0.8924
Epoch 30/30
1719/1719 [==============================] - 5s 3ms/step - loss: 0.2272 - accuracy: 0.9183
- val_loss: 0.3014 - val_accuracy: 0.8934
```

testing tensorboard

In [147…

```
test_logdir = get_run_logdir()
writer = tf.summary.create_file_writer(test_logdir)
with writer.as_default():
    for step in range(1, 1000 + 1):
        tf.summary.scalar("my_scalar", np.sin(step / 10), step=step)
        data = (np.random.randn(100) + 2) * step / 100 # some random data
        tf.summary.histogram("my_hist", data, buckets=50, step=step)
        images = np.random.rand(2, 32, 32, 3) # random 32×32 RGB images
        tf.summary.image("my_images", images * step / 1000, step=step)
        texts = ["The step is " + str(step), "Its square is " + str(step**2)]
        tf.summary.text("my_text", texts, step=step)
        sine_wave = tf.math.sin(tf.range(12000) / 48000 * 2 * np.pi * step)
        audio = tf.reshape(tf.cast(sine_wave, tf.float32), [1, -1, 1])
        tf.summary.audio("my_audio", audio, sample_rate=48000, step=step)
```

Exercises

In [4]:

```
(X_train_full, y_train_full), (X_test, y_test) = keras.datasets.mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.np
z
11493376/11490434 [==============================] - 5s 0us/step
11501568/11490434 [==============================] - 5s 0us/step
```

In [5]:

```
X_train_full.shape
```

Out[5]:

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

In [14]:

```
X_train_full,X_test=X_train_full/255.0, X_test/255.0
X_train,X_val= X_train_full[:50000],X_train_full[50000:]
y_train,y_val= y_train_full[:50000],y_train_full[50000:]
```

In [16]:

```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(300, activation="relu"),
    keras.layers.Dense(100, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
model.compile(loss="sparse_categorical_crossentropy",
              optimizer="sgd",
              metrics=["accuracy"])
```

In [24]:

```
run_logdir = get_run_logdir() # e.g., './my_logs/run_2019_06_07-15_15_22'
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=30,
                    validation_data=(X_val, y_val),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/30
  35/1563 [..............................] - ETA: 4s - loss: 0.6051 - accuracy: 0.7982
2022-01-17 12:17:49.233433: W tensorflow/core/framework/cpu_allocator_impl.cc:82] Allocati
on of 156800000 exceeds 10% of free system memory.
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6341 - accuracy: 0.7941
- val_loss: 0.6380 - val_accuracy: 0.7744
```

```
Epoch 2/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6234 - accuracy: 0.7966
- val_loss: 0.6259 - val_accuracy: 0.7859
Epoch 3/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6320 - accuracy: 0.7945
- val_loss: 0.6517 - val_accuracy: 0.7823
Epoch 4/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6207 - accuracy: 0.7992
- val_loss: 0.5516 - val_accuracy: 0.8237
Epoch 5/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6108 - accuracy: 0.8021
- val_loss: 0.5207 - val_accuracy: 0.8398
Epoch 6/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6061 - accuracy: 0.8047
- val_loss: 0.5217 - val_accuracy: 0.8468
Epoch 7/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6022 - accuracy: 0.8084
- val_loss: 0.5129 - val_accuracy: 0.8393
Epoch 8/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5992 - accuracy: 0.8054
- val_loss: 0.4997 - val_accuracy: 0.8458
Epoch 9/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6012 - accuracy: 0.8052
- val_loss: 0.6744 - val_accuracy: 0.7784
Epoch 10/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5959 - accuracy: 0.8089
- val_loss: 0.5471 - val_accuracy: 0.8371
Epoch 11/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5802 - accuracy: 0.8146
- val_loss: 0.4790 - val_accuracy: 0.8556
Epoch 12/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5792 - accuracy: 0.8126
- val_loss: 0.7842 - val_accuracy: 0.7267
Epoch 13/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5787 - accuracy: 0.8131
- val_loss: 0.5287 - val_accuracy: 0.8252
Epoch 14/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5725 - accuracy: 0.8167
- val_loss: 0.5128 - val_accuracy: 0.8385
Epoch 15/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5695 - accuracy: 0.8176
- val_loss: 0.5714 - val_accuracy: 0.8147
Epoch 16/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5714 - accuracy: 0.8165
- val_loss: 0.6771 - val_accuracy: 0.7670
Epoch 17/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5617 - accuracy: 0.8198
- val_loss: 0.6041 - val_accuracy: 0.8011
Epoch 18/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5543 - accuracy: 0.8243
- val_loss: 0.6374 - val_accuracy: 0.7694
Epoch 19/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5564 - accuracy: 0.8222
- val_loss: 0.6842 - val_accuracy: 0.7862
Epoch 20/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5553 - accuracy: 0.8232
- val_loss: 0.6453 - val_accuracy: 0.7746
Epoch 21/30
1563/1563 [==============================] - 5s 4ms/step - loss: 0.5465 - accuracy: 0.8237
- val_loss: 0.5264 - val_accuracy: 0.8367
Epoch 22/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5479 - accuracy: 0.8262
- val_loss: 0.9728 - val_accuracy: 0.6472
Epoch 23/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5380 - accuracy: 0.8308
- val_loss: 0.5093 - val_accuracy: 0.8390
```

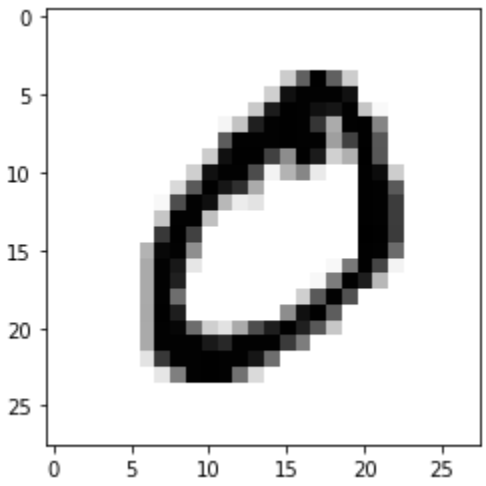
```
Epoch 24/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5359 - accuracy: 0.8295
- val_loss: 0.5114 - val_accuracy: 0.8388
Epoch 25/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5355 - accuracy: 0.8292
- val_loss: 0.6361 - val_accuracy: 0.7943
Epoch 26/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5330 - accuracy: 0.8303
- val_loss: 0.7011 - val_accuracy: 0.7631
Epoch 27/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5283 - accuracy: 0.8327
- val_loss: 0.4589 - val_accuracy: 0.8562
Epoch 28/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5236 - accuracy: 0.8354
- val_loss: 0.5000 - val_accuracy: 0.8484
Epoch 29/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5244 - accuracy: 0.8354
- val_loss: 0.5284 - val_accuracy: 0.8243
Epoch 30/30
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5156 - accuracy: 0.8384
- val_loss: 0.5347 - val_accuracy: 0.8262
```

In [18]:
```
y_train[1]
```

Out[18]:
```
0
```

In [19]:
```
plt.imshow(X_train[1],cmap='binary')
```

Out[19]:
```
<matplotlib.image.AxesImage at 0x7f77a7af9c10>
```



In [21]:
```
model.predict(np.array([X_train[1]]))
```

Out[21]:
```
array([[0.3476927 , 0.02369759, 0.10219069, 0.10198592, 0.05189641,
        0.10287583, 0.1045155 , 0.03986404, 0.0845897 , 0.04069167]],
      dtype=float32)
```

In [25]:
```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(300, activation="relu"),
    keras.layers.Dense(500, activation="relu"),
    keras.layers.Dense(200, activation="relu"),
    keras.layers.Dense(50, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
model.compile(loss="sparse_categorical_crossentropy",
              optimizer="sgd",
```

```
                metrics=["accuracy"])
run_logdir = get_run_logdir() # e.g., './my_logs/run_2019_06_07-15_15_22'
```

In [28]:

```
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=30,
                    validation_data=(X_val, y_val),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5753 - accuracy: 0.8043
- val_loss: 1.0685 - val_accuracy: 0.6580
Epoch 2/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5776 - accuracy: 0.8042
- val_loss: 0.5348 - val_accuracy: 0.8218
Epoch 3/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5567 - accuracy: 0.8116
- val_loss: 0.6352 - val_accuracy: 0.7756
Epoch 4/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5498 - accuracy: 0.8131
- val_loss: 1.4053 - val_accuracy: 0.5094
Epoch 5/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.5530 - accuracy: 0.8142
- val_loss: 0.4122 - val_accuracy: 0.8653
Epoch 6/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.5379 - accuracy: 0.8174
- val_loss: 0.6899 - val_accuracy: 0.7696
Epoch 7/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.5287 - accuracy: 0.8238
- val_loss: 0.5011 - val_accuracy: 0.8393
Epoch 8/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5203 - accuracy: 0.8262
- val_loss: 0.5524 - val_accuracy: 0.8026
Epoch 9/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5178 - accuracy: 0.8276
- val_loss: 0.4377 - val_accuracy: 0.8584
Epoch 10/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5148 - accuracy: 0.8271
- val_loss: 0.4900 - val_accuracy: 0.8363
Epoch 11/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5105 - accuracy: 0.8279
- val_loss: 0.4403 - val_accuracy: 0.8461
Epoch 12/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.5017 - accuracy: 0.8332
- val_loss: 0.4248 - val_accuracy: 0.8646
Epoch 13/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4970 - accuracy: 0.8336
- val_loss: 0.9561 - val_accuracy: 0.6538
Epoch 14/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4864 - accuracy: 0.8384
- val_loss: 0.9034 - val_accuracy: 0.6925
Epoch 15/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4952 - accuracy: 0.8336
- val_loss: 0.5272 - val_accuracy: 0.8165
Epoch 16/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.4883 - accuracy: 0.8367
- val_loss: 0.5314 - val_accuracy: 0.8077
Epoch 17/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4754 - accuracy: 0.8405
- val_loss: 0.9157 - val_accuracy: 0.7168
Epoch 18/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4790 - accuracy: 0.8402
- val_loss: 0.4338 - val_accuracy: 0.8545
Epoch 19/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4705 - accuracy: 0.8423
```

```
- val_loss: 0.4156 - val_accuracy: 0.8656
Epoch 20/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4607 - accuracy: 0.8469
- val_loss: 0.3387 - val_accuracy: 0.8921
Epoch 21/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4625 - accuracy: 0.8465
- val_loss: 0.4778 - val_accuracy: 0.8402
Epoch 22/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4573 - accuracy: 0.8473
- val_loss: 0.6612 - val_accuracy: 0.7667
Epoch 23/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.4556 - accuracy: 0.8486
- val_loss: 1.2874 - val_accuracy: 0.6020
Epoch 24/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4613 - accuracy: 0.8458
- val_loss: 0.3260 - val_accuracy: 0.8970
Epoch 25/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4446 - accuracy: 0.8527
- val_loss: 0.9706 - val_accuracy: 0.6727
Epoch 26/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4503 - accuracy: 0.8493
- val_loss: 0.6389 - val_accuracy: 0.7822
Epoch 27/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.4381 - accuracy: 0.8565
- val_loss: 0.5287 - val_accuracy: 0.8166
Epoch 28/30
1563/1563 [==============================] - 7s 5ms/step - loss: 0.4371 - accuracy: 0.8553
- val_loss: 0.4163 - val_accuracy: 0.8558
Epoch 29/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4359 - accuracy: 0.8547
- val_loss: 0.3678 - val_accuracy: 0.8785
Epoch 30/30
1563/1563 [==============================] - 8s 5ms/step - loss: 0.4318 - accuracy: 0.8584
- val_loss: 0.3768 - val_accuracy: 0.8762
```

In [29]:

```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(200, activation="relu"),
    keras.layers.Dense(50, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
model.compile(loss="sparse_categorical_crossentropy",
              optimizer="sgd",
              metrics=["accuracy"])
```

In [30]:

```
run_logdir = get_run_logdir()
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=100,
                    validation_data=(X_val, y_val),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2999 - accuracy: 0.1165
- val_loss: 2.3001 - val_accuracy: 0.1064
Epoch 2/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2993 - accuracy: 0.1136
- val_loss: 2.2998 - val_accuracy: 0.1064
Epoch 3/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2989 - accuracy: 0.1136
- val_loss: 2.2994 - val_accuracy: 0.1064
Epoch 4/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2984 - accuracy: 0.1136
- val_loss: 2.2990 - val_accuracy: 0.1064
```

```
Epoch 5/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2982 - accuracy: 0.1136
- val_loss: 2.2986 - val_accuracy: 0.1064
Epoch 6/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2977 - accuracy: 0.1136
- val_loss: 2.2983 - val_accuracy: 0.1064
Epoch 7/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2972 - accuracy: 0.1136
- val_loss: 2.2974 - val_accuracy: 0.1064
Epoch 8/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2968 - accuracy: 0.1136
- val_loss: 2.2968 - val_accuracy: 0.1064
Epoch 9/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2962 - accuracy: 0.1136
- val_loss: 2.2963 - val_accuracy: 0.1064
Epoch 10/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2956 - accuracy: 0.1136
- val_loss: 2.2964 - val_accuracy: 0.1064
Epoch 11/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2948 - accuracy: 0.1136
- val_loss: 2.2952 - val_accuracy: 0.1064
Epoch 12/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2942 - accuracy: 0.1138
- val_loss: 2.2947 - val_accuracy: 0.1064
Epoch 13/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2934 - accuracy: 0.1136
- val_loss: 2.2935 - val_accuracy: 0.1064
Epoch 14/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2924 - accuracy: 0.1136
- val_loss: 2.2922 - val_accuracy: 0.1064
Epoch 15/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2915 - accuracy: 0.1136
- val_loss: 2.2910 - val_accuracy: 0.1064
Epoch 16/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2903 - accuracy: 0.1138
- val_loss: 2.2899 - val_accuracy: 0.1064
Epoch 17/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2889 - accuracy: 0.1144
- val_loss: 2.2885 - val_accuracy: 0.1064
Epoch 18/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2874 - accuracy: 0.1149
- val_loss: 2.2871 - val_accuracy: 0.1064
Epoch 19/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2857 - accuracy: 0.1184
- val_loss: 2.2846 - val_accuracy: 0.1064
Epoch 20/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2836 - accuracy: 0.1159
- val_loss: 2.2824 - val_accuracy: 0.1064
Epoch 21/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2810 - accuracy: 0.1202
- val_loss: 2.2798 - val_accuracy: 0.1151
Epoch 22/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2781 - accuracy: 0.1354
- val_loss: 2.2766 - val_accuracy: 0.1064
Epoch 23/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2746 - accuracy: 0.1404
- val_loss: 2.2725 - val_accuracy: 0.1105
Epoch 24/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2702 - accuracy: 0.1725
- val_loss: 2.2674 - val_accuracy: 0.1738
Epoch 25/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2647 - accuracy: 0.1864
- val_loss: 2.2609 - val_accuracy: 0.3676
Epoch 26/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2579 - accuracy: 0.2157
- val_loss: 2.2534 - val_accuracy: 0.3642
```

```
Epoch 27/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2494 - accuracy: 0.2533
- val_loss: 2.2434 - val_accuracy: 0.1731
Epoch 28/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2381 - accuracy: 0.2673
- val_loss: 2.2316 - val_accuracy: 0.2462
Epoch 29/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2235 - accuracy: 0.2803
- val_loss: 2.2125 - val_accuracy: 0.2998
Epoch 30/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2044 - accuracy: 0.3118
- val_loss: 2.1917 - val_accuracy: 0.2859
Epoch 31/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.1789 - accuracy: 0.3339
- val_loss: 2.1596 - val_accuracy: 0.3458
Epoch 32/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.1451 - accuracy: 0.3400
- val_loss: 2.1247 - val_accuracy: 0.2701
Epoch 33/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.1017 - accuracy: 0.3619
- val_loss: 2.0741 - val_accuracy: 0.3525
Epoch 34/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.0483 - accuracy: 0.3731
- val_loss: 2.0277 - val_accuracy: 0.3324
Epoch 35/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.9874 - accuracy: 0.3908
- val_loss: 1.9393 - val_accuracy: 0.4417
Epoch 36/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.9242 - accuracy: 0.4123
- val_loss: 1.8711 - val_accuracy: 0.4680
Epoch 37/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.8603 - accuracy: 0.4258
- val_loss: 1.8148 - val_accuracy: 0.4337
Epoch 38/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.8033 - accuracy: 0.4431
- val_loss: 1.7664 - val_accuracy: 0.4776
Epoch 39/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.7540 - accuracy: 0.4520
- val_loss: 1.6955 - val_accuracy: 0.4798
Epoch 40/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.7137 - accuracy: 0.4551
- val_loss: 1.6208 - val_accuracy: 0.4519
Epoch 41/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.6748 - accuracy: 0.4680
- val_loss: 1.5478 - val_accuracy: 0.5635
Epoch 42/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.6099 - accuracy: 0.4856
- val_loss: 1.7905 - val_accuracy: 0.3906
Epoch 43/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.5478 - accuracy: 0.5011
- val_loss: 1.4175 - val_accuracy: 0.5625
Epoch 44/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.4723 - accuracy: 0.5204
- val_loss: 1.3429 - val_accuracy: 0.6172
Epoch 45/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.4102 - accuracy: 0.5351
- val_loss: 1.2737 - val_accuracy: 0.5947
Epoch 46/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.3452 - accuracy: 0.5481
- val_loss: 1.2492 - val_accuracy: 0.6112
Epoch 47/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.2789 - accuracy: 0.5611
- val_loss: 1.2309 - val_accuracy: 0.5361
Epoch 48/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.2391 - accuracy: 0.5688
- val_loss: 1.1540 - val_accuracy: 0.5821
```

```
Epoch 49/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.2003 - accuracy: 0.5758
- val_loss: 1.8291 - val_accuracy: 0.4221
Epoch 50/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.1730 - accuracy: 0.5788
- val_loss: 1.0372 - val_accuracy: 0.6659
Epoch 51/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.1621 - accuracy: 0.5780
- val_loss: 1.1659 - val_accuracy: 0.5343
Epoch 52/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.1327 - accuracy: 0.5894
- val_loss: 1.0350 - val_accuracy: 0.6187
Epoch 53/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.1130 - accuracy: 0.5941
- val_loss: 1.1407 - val_accuracy: 0.5535
Epoch 54/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0844 - accuracy: 0.6060
- val_loss: 1.8190 - val_accuracy: 0.3471
Epoch 55/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0688 - accuracy: 0.6140
- val_loss: 0.9149 - val_accuracy: 0.7035
Epoch 56/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0507 - accuracy: 0.6181
- val_loss: 1.1839 - val_accuracy: 0.5163
Epoch 57/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0403 - accuracy: 0.6241
- val_loss: 1.2924 - val_accuracy: 0.4762
Epoch 58/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0174 - accuracy: 0.6318
- val_loss: 0.9859 - val_accuracy: 0.6774
Epoch 59/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0117 - accuracy: 0.6344
- val_loss: 0.8894 - val_accuracy: 0.6975
Epoch 60/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9905 - accuracy: 0.6478
- val_loss: 0.9139 - val_accuracy: 0.6889
Epoch 61/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9747 - accuracy: 0.6507
- val_loss: 0.9652 - val_accuracy: 0.6869
Epoch 62/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9641 - accuracy: 0.6582
- val_loss: 0.8359 - val_accuracy: 0.7066
Epoch 63/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9561 - accuracy: 0.6627
- val_loss: 0.8725 - val_accuracy: 0.6926
Epoch 64/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9330 - accuracy: 0.6702
- val_loss: 0.8080 - val_accuracy: 0.7329
Epoch 65/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9143 - accuracy: 0.6810
- val_loss: 1.2512 - val_accuracy: 0.5189
Epoch 66/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9051 - accuracy: 0.6862
- val_loss: 0.7950 - val_accuracy: 0.7321
Epoch 67/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8835 - accuracy: 0.6945
- val_loss: 0.8759 - val_accuracy: 0.7080
Epoch 68/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8742 - accuracy: 0.7023
- val_loss: 0.7273 - val_accuracy: 0.7760
Epoch 69/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8702 - accuracy: 0.7027
- val_loss: 0.7599 - val_accuracy: 0.7626
Epoch 70/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.8402 - accuracy: 0.7140
- val_loss: 0.8180 - val_accuracy: 0.7442
```

```
Epoch 71/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8282 - accuracy: 0.7215
- val_loss: 0.7877 - val_accuracy: 0.7417
Epoch 72/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.8188 - accuracy: 0.7236
- val_loss: 0.6862 - val_accuracy: 0.7800
Epoch 73/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8098 - accuracy: 0.7281
- val_loss: 0.9714 - val_accuracy: 0.6375
Epoch 74/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7945 - accuracy: 0.7355
- val_loss: 1.1462 - val_accuracy: 0.5695
Epoch 75/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7756 - accuracy: 0.7421
- val_loss: 0.9704 - val_accuracy: 0.6172
Epoch 76/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7592 - accuracy: 0.7507
- val_loss: 0.7710 - val_accuracy: 0.7437
Epoch 77/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7559 - accuracy: 0.7511
- val_loss: 0.6289 - val_accuracy: 0.8051
Epoch 78/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7384 - accuracy: 0.7576
- val_loss: 1.2113 - val_accuracy: 0.5320
Epoch 79/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7272 - accuracy: 0.7610
- val_loss: 0.7112 - val_accuracy: 0.7792
Epoch 80/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7102 - accuracy: 0.7690
- val_loss: 0.7079 - val_accuracy: 0.7854
Epoch 81/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7101 - accuracy: 0.7692
- val_loss: 0.9301 - val_accuracy: 0.6765
Epoch 82/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6985 - accuracy: 0.7726
- val_loss: 0.5887 - val_accuracy: 0.8218
Epoch 83/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6855 - accuracy: 0.7786
- val_loss: 0.5931 - val_accuracy: 0.8141
Epoch 84/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6698 - accuracy: 0.7842
- val_loss: 0.9489 - val_accuracy: 0.6343
Epoch 85/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6655 - accuracy: 0.7855
- val_loss: 0.6700 - val_accuracy: 0.7729
Epoch 86/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6639 - accuracy: 0.7862
- val_loss: 0.6697 - val_accuracy: 0.7768
Epoch 87/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6510 - accuracy: 0.7913
- val_loss: 0.6122 - val_accuracy: 0.7983
Epoch 88/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6516 - accuracy: 0.7873
- val_loss: 0.5963 - val_accuracy: 0.8185
Epoch 89/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6407 - accuracy: 0.7943
- val_loss: 0.5417 - val_accuracy: 0.8325
Epoch 90/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6369 - accuracy: 0.7952
- val_loss: 0.5295 - val_accuracy: 0.8451
Epoch 91/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6281 - accuracy: 0.7992
- val_loss: 0.6487 - val_accuracy: 0.7843
Epoch 92/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6242 - accuracy: 0.8000
- val_loss: 0.6178 - val_accuracy: 0.7927
```

```
Epoch 93/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6218 - accuracy: 0.8004
- val_loss: 0.7062 - val_accuracy: 0.7578
Epoch 94/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6190 - accuracy: 0.8015
- val_loss: 0.5386 - val_accuracy: 0.8322
Epoch 95/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6030 - accuracy: 0.8076
- val_loss: 0.6374 - val_accuracy: 0.8036
Epoch 96/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6063 - accuracy: 0.8061
- val_loss: 0.6216 - val_accuracy: 0.7943
Epoch 97/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6014 - accuracy: 0.8070
- val_loss: 0.5345 - val_accuracy: 0.8413
Epoch 98/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5970 - accuracy: 0.8109
- val_loss: 0.5209 - val_accuracy: 0.8349
Epoch 99/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5960 - accuracy: 0.8086
- val_loss: 0.6470 - val_accuracy: 0.7923
Epoch 100/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5934 - accuracy: 0.8094
- val_loss: 0.5075 - val_accuracy: 0.8521
```

In [31]:

```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(200, activation="relu"),
    keras.layers.Dense(100, activation="relu"),
    keras.layers.Dense(50, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
model.compile(loss="sparse_categorical_crossentropy",
              optimizer="sgd",
              metrics=["accuracy"])
```

In [32]:

```
run_logdir = get_run_logdir()
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=100,
                    validation_data=(X_val, y_val),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2997 - accuracy: 0.1139
- val_loss: 2.3000 - val_accuracy: 0.1064
Epoch 2/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2991 - accuracy: 0.1136
- val_loss: 2.2995 - val_accuracy: 0.1064
Epoch 3/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2986 - accuracy: 0.1136
- val_loss: 2.2995 - val_accuracy: 0.1064
Epoch 4/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2982 - accuracy: 0.1136
- val_loss: 2.2990 - val_accuracy: 0.1064
Epoch 5/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2977 - accuracy: 0.1136
- val_loss: 2.2985 - val_accuracy: 0.1064
Epoch 6/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2971 - accuracy: 0.1136
- val_loss: 2.2977 - val_accuracy: 0.1064
Epoch 7/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2965 - accuracy: 0.1136
- val_loss: 2.2973 - val_accuracy: 0.1064
```

```
Epoch 8/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2956 - accuracy: 0.1143
- val_loss: 2.2958 - val_accuracy: 0.1064
Epoch 9/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2946 - accuracy: 0.1166
- val_loss: 2.2949 - val_accuracy: 0.1908
Epoch 10/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2935 - accuracy: 0.1190
- val_loss: 2.2942 - val_accuracy: 0.1064
Epoch 11/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2920 - accuracy: 0.1179
- val_loss: 2.2921 - val_accuracy: 0.1064
Epoch 12/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2902 - accuracy: 0.1226
- val_loss: 2.2897 - val_accuracy: 0.1064
Epoch 13/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2877 - accuracy: 0.1320
- val_loss: 2.2871 - val_accuracy: 0.1064
Epoch 14/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2846 - accuracy: 0.1379
- val_loss: 2.2836 - val_accuracy: 0.2048
Epoch 15/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2799 - accuracy: 0.1629
- val_loss: 2.2785 - val_accuracy: 0.1064
Epoch 16/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2732 - accuracy: 0.1790
- val_loss: 2.2690 - val_accuracy: 0.2402
Epoch 17/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2618 - accuracy: 0.2013
- val_loss: 2.2547 - val_accuracy: 0.2063
Epoch 18/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2423 - accuracy: 0.2182
- val_loss: 2.2368 - val_accuracy: 0.1438
Epoch 19/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2040 - accuracy: 0.2330
- val_loss: 2.1719 - val_accuracy: 0.2471
Epoch 20/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.1330 - accuracy: 0.2505
- val_loss: 2.0756 - val_accuracy: 0.2932
Epoch 21/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.0863 - accuracy: 0.2666
- val_loss: 1.9892 - val_accuracy: 0.3834
Epoch 22/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.0557 - accuracy: 0.2805
- val_loss: 1.9952 - val_accuracy: 0.3071
Epoch 23/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.0210 - accuracy: 0.2954
- val_loss: 3.0306 - val_accuracy: 0.1074
Epoch 24/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.9648 - accuracy: 0.3240
- val_loss: 1.8054 - val_accuracy: 0.4082
Epoch 25/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.8884 - accuracy: 0.3530
- val_loss: 1.7427 - val_accuracy: 0.4008
Epoch 26/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.7992 - accuracy: 0.3677
- val_loss: 2.2499 - val_accuracy: 0.2944
Epoch 27/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.7598 - accuracy: 0.3695
- val_loss: 1.5398 - val_accuracy: 0.5226
Epoch 28/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.6876 - accuracy: 0.3962
- val_loss: 1.7457 - val_accuracy: 0.3862
Epoch 29/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.6255 - accuracy: 0.4218
- val_loss: 1.7945 - val_accuracy: 0.3516
```

```
Epoch 30/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.5439 - accuracy: 0.4513
- val_loss: 1.2535 - val_accuracy: 0.6370
Epoch 31/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.4712 - accuracy: 0.4714
- val_loss: 1.2243 - val_accuracy: 0.5908
Epoch 32/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.4074 - accuracy: 0.4893
- val_loss: 1.0973 - val_accuracy: 0.6596
Epoch 33/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.3751 - accuracy: 0.5006
- val_loss: 1.1831 - val_accuracy: 0.5914
Epoch 34/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.3337 - accuracy: 0.5175
- val_loss: 1.1003 - val_accuracy: 0.6200
Epoch 35/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.2782 - accuracy: 0.5374
- val_loss: 1.1548 - val_accuracy: 0.5659
Epoch 36/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.2495 - accuracy: 0.5515
- val_loss: 0.9287 - val_accuracy: 0.7244
Epoch 37/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.1970 - accuracy: 0.5711
- val_loss: 1.0536 - val_accuracy: 0.5964
Epoch 38/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.1564 - accuracy: 0.5867
- val_loss: 0.9999 - val_accuracy: 0.6699
Epoch 39/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.1152 - accuracy: 0.6029
- val_loss: 1.0615 - val_accuracy: 0.5858
Epoch 40/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0783 - accuracy: 0.6183
- val_loss: 1.7835 - val_accuracy: 0.3162
Epoch 41/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0391 - accuracy: 0.6352
- val_loss: 1.0212 - val_accuracy: 0.6386
Epoch 42/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0174 - accuracy: 0.6426
- val_loss: 1.2624 - val_accuracy: 0.5174
Epoch 43/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9805 - accuracy: 0.6578
- val_loss: 0.8448 - val_accuracy: 0.7009
Epoch 44/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9635 - accuracy: 0.6619
- val_loss: 0.8132 - val_accuracy: 0.7293
Epoch 45/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9584 - accuracy: 0.6674
- val_loss: 0.8458 - val_accuracy: 0.7034
Epoch 46/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9068 - accuracy: 0.6854
- val_loss: 0.9781 - val_accuracy: 0.6620
Epoch 47/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8910 - accuracy: 0.6907
- val_loss: 0.6997 - val_accuracy: 0.7537
Epoch 48/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8565 - accuracy: 0.7083
- val_loss: 0.6790 - val_accuracy: 0.8043
Epoch 49/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8410 - accuracy: 0.7155
- val_loss: 0.8166 - val_accuracy: 0.7126
Epoch 50/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8093 - accuracy: 0.7267
- val_loss: 1.0272 - val_accuracy: 0.6203
Epoch 51/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7879 - accuracy: 0.7319
- val_loss: 0.6266 - val_accuracy: 0.8075
```

```
Epoch 52/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7884 - accuracy: 0.7326
- val_loss: 0.8100 - val_accuracy: 0.7199
Epoch 53/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7654 - accuracy: 0.7389
- val_loss: 1.2339 - val_accuracy: 0.5509
Epoch 54/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7448 - accuracy: 0.7463
- val_loss: 0.6092 - val_accuracy: 0.7998
Epoch 55/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7449 - accuracy: 0.7463
- val_loss: 1.6070 - val_accuracy: 0.4869
Epoch 56/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7238 - accuracy: 0.7556
- val_loss: 0.5604 - val_accuracy: 0.8275
Epoch 57/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7260 - accuracy: 0.7546
- val_loss: 0.6160 - val_accuracy: 0.7912
Epoch 58/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6918 - accuracy: 0.7639
- val_loss: 0.9370 - val_accuracy: 0.6536
Epoch 59/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6817 - accuracy: 0.7725
- val_loss: 0.8026 - val_accuracy: 0.7446
Epoch 60/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6822 - accuracy: 0.7734
- val_loss: 0.7681 - val_accuracy: 0.7243
Epoch 61/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6679 - accuracy: 0.7768
- val_loss: 0.7169 - val_accuracy: 0.7634
Epoch 62/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6611 - accuracy: 0.7794
- val_loss: 0.6489 - val_accuracy: 0.7846
Epoch 63/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6470 - accuracy: 0.7845
- val_loss: 0.7653 - val_accuracy: 0.7323
Epoch 64/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6376 - accuracy: 0.7867
- val_loss: 0.6304 - val_accuracy: 0.7820
Epoch 65/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6329 - accuracy: 0.7894
- val_loss: 0.6074 - val_accuracy: 0.7815
Epoch 66/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6209 - accuracy: 0.7951
- val_loss: 0.4648 - val_accuracy: 0.8626
Epoch 67/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6087 - accuracy: 0.7974
- val_loss: 0.5416 - val_accuracy: 0.8272
Epoch 68/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6008 - accuracy: 0.8003
- val_loss: 0.7950 - val_accuracy: 0.7096
Epoch 69/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5942 - accuracy: 0.8020
- val_loss: 0.5117 - val_accuracy: 0.8345
Epoch 70/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5803 - accuracy: 0.8109
- val_loss: 0.8924 - val_accuracy: 0.6865
Epoch 71/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5816 - accuracy: 0.8077
- val_loss: 0.5222 - val_accuracy: 0.8257
Epoch 72/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5709 - accuracy: 0.8131
- val_loss: 0.7070 - val_accuracy: 0.7530
Epoch 73/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5617 - accuracy: 0.8180
- val_loss: 0.6103 - val_accuracy: 0.7893
```

```
Epoch 74/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5638 - accuracy: 0.8158
- val_loss: 0.5200 - val_accuracy: 0.8318
Epoch 75/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5551 - accuracy: 0.8172
- val_loss: 0.4708 - val_accuracy: 0.8501
Epoch 76/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5550 - accuracy: 0.8189
- val_loss: 0.4921 - val_accuracy: 0.8477
Epoch 77/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5391 - accuracy: 0.8239
- val_loss: 0.6080 - val_accuracy: 0.7853
Epoch 78/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5449 - accuracy: 0.8211
- val_loss: 0.6711 - val_accuracy: 0.7610
Epoch 79/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5305 - accuracy: 0.8276
- val_loss: 0.5481 - val_accuracy: 0.8125
Epoch 80/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5281 - accuracy: 0.8293
- val_loss: 0.5201 - val_accuracy: 0.8438
Epoch 81/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5279 - accuracy: 0.8289
- val_loss: 0.4682 - val_accuracy: 0.8462
Epoch 82/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5159 - accuracy: 0.8338
- val_loss: 0.7042 - val_accuracy: 0.7576
Epoch 83/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5125 - accuracy: 0.8328
- val_loss: 0.4660 - val_accuracy: 0.8472
Epoch 84/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5114 - accuracy: 0.8338
- val_loss: 0.7474 - val_accuracy: 0.7302
Epoch 85/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5035 - accuracy: 0.8366
- val_loss: 0.5460 - val_accuracy: 0.8317
Epoch 86/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5034 - accuracy: 0.8359
- val_loss: 0.5566 - val_accuracy: 0.8065
Epoch 87/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5025 - accuracy: 0.8379
- val_loss: 0.5235 - val_accuracy: 0.8331
Epoch 88/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4993 - accuracy: 0.8392
- val_loss: 0.4691 - val_accuracy: 0.8466
Epoch 89/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4882 - accuracy: 0.8432
- val_loss: 0.3679 - val_accuracy: 0.8863
Epoch 90/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4902 - accuracy: 0.8420
- val_loss: 0.5599 - val_accuracy: 0.8082
Epoch 91/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4870 - accuracy: 0.8434
- val_loss: 1.9696 - val_accuracy: 0.4556
Epoch 92/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4858 - accuracy: 0.8437
- val_loss: 0.6535 - val_accuracy: 0.7733
Epoch 93/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4757 - accuracy: 0.8489
- val_loss: 0.5473 - val_accuracy: 0.8213
Epoch 94/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4768 - accuracy: 0.8474
- val_loss: 0.5138 - val_accuracy: 0.8279
Epoch 95/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4661 - accuracy: 0.8517
- val_loss: 0.4909 - val_accuracy: 0.8331
```

```
Epoch 96/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4725 - accuracy: 0.8476
- val_loss: 0.5149 - val_accuracy: 0.8229
Epoch 97/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4608 - accuracy: 0.8517
- val_loss: 0.5266 - val_accuracy: 0.8277
Epoch 98/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4613 - accuracy: 0.8520
- val_loss: 0.4843 - val_accuracy: 0.8379
Epoch 99/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4562 - accuracy: 0.8530
- val_loss: 0.5304 - val_accuracy: 0.8206
Epoch 100/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4562 - accuracy: 0.8544
- val_loss: 0.4436 - val_accuracy: 0.8615
```

In [34]:

```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(200, activation="relu"),
    keras.layers.Dense(100, activation="relu"),
    keras.layers.Dense(50, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
model.compile(loss="sparse_categorical_crossentropy",
              optimizer=keras.optimizers.SGD(lr=0.05),
              metrics=["accuracy"])
```

In [35]:

```
run_logdir = get_run_logdir()
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=100,
                    validation_data=(X_val, y_val),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.3008 - accuracy: 0.1135
- val_loss: 2.3008 - val_accuracy: 0.1064
Epoch 2/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2997 - accuracy: 0.1147
- val_loss: 2.2989 - val_accuracy: 0.1064
Epoch 3/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2980 - accuracy: 0.1181
- val_loss: 2.2977 - val_accuracy: 0.1064
Epoch 4/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2948 - accuracy: 0.1271
- val_loss: 2.2920 - val_accuracy: 0.1090
Epoch 5/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2840 - accuracy: 0.1473
- val_loss: 2.2705 - val_accuracy: 0.1952
Epoch 6/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2417 - accuracy: 0.1823
- val_loss: 2.3650 - val_accuracy: 0.0991
Epoch 7/100
1563/1563 [==============================] - 6s 4ms/step - loss: 2.1700 - accuracy: 0.2104
- val_loss: 2.1547 - val_accuracy: 0.1128
Epoch 8/100
1563/1563 [==============================] - 6s 4ms/step - loss: 2.0993 - accuracy: 0.2392
- val_loss: 1.9448 - val_accuracy: 0.2625
Epoch 9/100
1563/1563 [==============================] - 6s 4ms/step - loss: 2.0224 - accuracy: 0.2688
- val_loss: 2.0939 - val_accuracy: 0.1797
Epoch 10/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.9517 - accuracy: 0.2980
- val_loss: 1.8775 - val_accuracy: 0.3007
```

```
Epoch 11/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.8866 - accuracy: 0.3269
- val_loss: 1.9379 - val_accuracy: 0.3474
Epoch 12/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.8275 - accuracy: 0.3427
- val_loss: 2.1014 - val_accuracy: 0.2204
Epoch 13/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.7647 - accuracy: 0.3653
- val_loss: 1.8630 - val_accuracy: 0.4059
Epoch 14/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.7085 - accuracy: 0.3870
- val_loss: 2.6249 - val_accuracy: 0.1214
Epoch 15/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.6384 - accuracy: 0.4122
- val_loss: 1.5143 - val_accuracy: 0.4282
Epoch 16/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.5815 - accuracy: 0.4344
- val_loss: 1.8603 - val_accuracy: 0.2496
Epoch 17/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.5114 - accuracy: 0.4551
- val_loss: 2.5549 - val_accuracy: 0.2375
Epoch 18/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.4573 - accuracy: 0.4777
- val_loss: 1.6501 - val_accuracy: 0.3990
Epoch 19/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.3777 - accuracy: 0.5041
- val_loss: 1.4966 - val_accuracy: 0.4116
Epoch 20/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.3384 - accuracy: 0.5208
- val_loss: 1.3626 - val_accuracy: 0.4697
Epoch 21/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.2570 - accuracy: 0.5522
- val_loss: 1.3858 - val_accuracy: 0.5037
Epoch 22/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.1980 - accuracy: 0.5746
- val_loss: 1.0685 - val_accuracy: 0.6150
Epoch 23/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.1569 - accuracy: 0.5896
- val_loss: 0.7526 - val_accuracy: 0.7749
Epoch 24/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.0944 - accuracy: 0.6126
- val_loss: 0.9655 - val_accuracy: 0.6404
Epoch 25/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.0542 - accuracy: 0.6282
- val_loss: 0.7683 - val_accuracy: 0.7409
Epoch 26/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9946 - accuracy: 0.6498
- val_loss: 1.0172 - val_accuracy: 0.6059
Epoch 27/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9575 - accuracy: 0.6640
- val_loss: 1.0104 - val_accuracy: 0.6408
Epoch 28/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9244 - accuracy: 0.6755
- val_loss: 1.3290 - val_accuracy: 0.5309
Epoch 29/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8993 - accuracy: 0.6864
- val_loss: 0.9104 - val_accuracy: 0.6448
Epoch 30/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8659 - accuracy: 0.6978
- val_loss: 1.1133 - val_accuracy: 0.6005
Epoch 31/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8645 - accuracy: 0.6985
- val_loss: 0.6661 - val_accuracy: 0.7663
Epoch 32/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8666 - accuracy: 0.7002
- val_loss: 0.8101 - val_accuracy: 0.7393
```

```
Epoch 33/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8425 - accuracy: 0.7115
- val_loss: 0.5117 - val_accuracy: 0.8504
Epoch 34/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8109 - accuracy: 0.7193
- val_loss: 1.6686 - val_accuracy: 0.4485
Epoch 35/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7837 - accuracy: 0.7283
- val_loss: 1.0932 - val_accuracy: 0.6253
Epoch 36/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7620 - accuracy: 0.7370
- val_loss: 0.7537 - val_accuracy: 0.7233
Epoch 37/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7575 - accuracy: 0.7397
- val_loss: 1.2300 - val_accuracy: 0.6398
Epoch 38/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7317 - accuracy: 0.7478
- val_loss: 0.6078 - val_accuracy: 0.7879
Epoch 39/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7082 - accuracy: 0.7547
- val_loss: 0.6473 - val_accuracy: 0.7668
Epoch 40/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6974 - accuracy: 0.7619
- val_loss: 0.5095 - val_accuracy: 0.8369
Epoch 41/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6747 - accuracy: 0.7690
- val_loss: 0.6349 - val_accuracy: 0.7650
Epoch 42/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6527 - accuracy: 0.7779
- val_loss: 0.7399 - val_accuracy: 0.7245
Epoch 43/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6460 - accuracy: 0.7803
- val_loss: 0.5406 - val_accuracy: 0.8139
Epoch 44/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6354 - accuracy: 0.7838
- val_loss: 0.4628 - val_accuracy: 0.8466
Epoch 45/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6190 - accuracy: 0.7892
- val_loss: 0.8028 - val_accuracy: 0.7246
Epoch 46/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6070 - accuracy: 0.7927
- val_loss: 0.8894 - val_accuracy: 0.6914
Epoch 47/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5958 - accuracy: 0.7981
- val_loss: 0.5570 - val_accuracy: 0.8061
Epoch 48/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5848 - accuracy: 0.7999
- val_loss: 0.6629 - val_accuracy: 0.7507
Epoch 49/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5763 - accuracy: 0.8048
- val_loss: 0.4932 - val_accuracy: 0.8318
Epoch 50/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5653 - accuracy: 0.8086
- val_loss: 0.5054 - val_accuracy: 0.8205
Epoch 51/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5685 - accuracy: 0.8069
- val_loss: 0.4202 - val_accuracy: 0.8537
Epoch 52/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5480 - accuracy: 0.8128
- val_loss: 0.9777 - val_accuracy: 0.6310
Epoch 53/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5417 - accuracy: 0.8158
- val_loss: 0.6091 - val_accuracy: 0.7787
Epoch 54/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5393 - accuracy: 0.8173
- val_loss: 0.5165 - val_accuracy: 0.8351
```

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Epoch 55/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5273 - accuracy: 0.8218
- val_loss: 0.4246 - val_accuracy: 0.8615
Epoch 56/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5134 - accuracy: 0.8270
- val_loss: 0.7608 - val_accuracy: 0.7366
Epoch 57/100
1563/1563 [==============================] - 6s 4ms/step - loss: 0.5080 - accuracy: 0.8283
- val_loss: 0.5446 - val_accuracy: 0.8193
Epoch 58/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5016 - accuracy: 0.8310
- val_loss: 0.7198 - val_accuracy: 0.7668
Epoch 59/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4975 - accuracy: 0.8326
- val_loss: 1.2154 - val_accuracy: 0.6290
Epoch 60/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4840 - accuracy: 0.8355
- val_loss: 0.4105 - val_accuracy: 0.8647
Epoch 61/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4950 - accuracy: 0.8334
- val_loss: 0.3829 - val_accuracy: 0.8734
Epoch 62/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4843 - accuracy: 0.8385
- val_loss: 0.4726 - val_accuracy: 0.8421
Epoch 63/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4744 - accuracy: 0.8411
- val_loss: 0.3868 - val_accuracy: 0.8752
Epoch 64/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4742 - accuracy: 0.8425
- val_loss: 1.0187 - val_accuracy: 0.6299
Epoch 65/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4638 - accuracy: 0.8446
- val_loss: 0.3737 - val_accuracy: 0.8783
Epoch 66/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4638 - accuracy: 0.8451
- val_loss: 0.4998 - val_accuracy: 0.8310
Epoch 67/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4496 - accuracy: 0.8489
- val_loss: 0.9572 - val_accuracy: 0.6913
Epoch 68/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4434 - accuracy: 0.8509
- val_loss: 0.3460 - val_accuracy: 0.8860
Epoch 69/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4496 - accuracy: 0.8506
- val_loss: 0.7456 - val_accuracy: 0.7339
Epoch 70/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4339 - accuracy: 0.8565
- val_loss: 0.5183 - val_accuracy: 0.8209
Epoch 71/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4348 - accuracy: 0.8566
- val_loss: 0.3238 - val_accuracy: 0.8967
Epoch 72/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4371 - accuracy: 0.8548
- val_loss: 0.3101 - val_accuracy: 0.9054
Epoch 73/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4306 - accuracy: 0.8573
- val_loss: 0.3500 - val_accuracy: 0.8892
Epoch 74/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4304 - accuracy: 0.8574
- val_loss: 0.3480 - val_accuracy: 0.8848
Epoch 75/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4194 - accuracy: 0.8614
- val_loss: 0.4221 - val_accuracy: 0.8553
Epoch 76/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4079 - accuracy: 0.8651
- val_loss: 0.6385 - val_accuracy: 0.7858
```

```
Epoch 77/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4154 - accuracy: 0.8622
- val_loss: 0.3511 - val_accuracy: 0.8828
Epoch 78/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4081 - accuracy: 0.8640
- val_loss: 0.4328 - val_accuracy: 0.8559
Epoch 79/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4027 - accuracy: 0.8672
- val_loss: 0.4135 - val_accuracy: 0.8649
Epoch 80/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4054 - accuracy: 0.8655
- val_loss: 0.3772 - val_accuracy: 0.8754
Epoch 81/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3975 - accuracy: 0.8679
- val_loss: 0.3753 - val_accuracy: 0.8764
Epoch 82/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3947 - accuracy: 0.8688
- val_loss: 0.3195 - val_accuracy: 0.8974
Epoch 83/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3885 - accuracy: 0.8721
- val_loss: 0.2898 - val_accuracy: 0.9101
Epoch 84/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3855 - accuracy: 0.8733
- val_loss: 0.8450 - val_accuracy: 0.7157
Epoch 85/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3833 - accuracy: 0.8742
- val_loss: 0.3103 - val_accuracy: 0.8963
Epoch 86/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3835 - accuracy: 0.8730
- val_loss: 0.5918 - val_accuracy: 0.8110
Epoch 87/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3832 - accuracy: 0.8716
- val_loss: 0.2797 - val_accuracy: 0.9093
Epoch 88/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3800 - accuracy: 0.8749
- val_loss: 0.2801 - val_accuracy: 0.9112
Epoch 89/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3776 - accuracy: 0.8755
- val_loss: 0.3504 - val_accuracy: 0.8863
Epoch 90/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3695 - accuracy: 0.8776
- val_loss: 0.3809 - val_accuracy: 0.8712
Epoch 91/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3706 - accuracy: 0.8777
- val_loss: 0.3319 - val_accuracy: 0.8953
Epoch 92/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3661 - accuracy: 0.8799
- val_loss: 0.5524 - val_accuracy: 0.8147
Epoch 93/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3636 - accuracy: 0.8807
- val_loss: 0.3549 - val_accuracy: 0.8763
Epoch 94/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3619 - accuracy: 0.8803
- val_loss: 0.3513 - val_accuracy: 0.8880
Epoch 95/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3633 - accuracy: 0.8806
- val_loss: 0.3638 - val_accuracy: 0.8801
Epoch 96/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3615 - accuracy: 0.8795
- val_loss: 0.3115 - val_accuracy: 0.9007
Epoch 97/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3593 - accuracy: 0.8826
- val_loss: 0.2969 - val_accuracy: 0.9025
Epoch 98/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3560 - accuracy: 0.8818
- val_loss: 0.4480 - val_accuracy: 0.8452
```

```
Epoch 99/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3534 - accuracy: 0.8822
- val_loss: 0.6616 - val_accuracy: 0.7762
Epoch 100/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.3472 - accuracy: 0.8860
- val_loss: 0.3113 - val_accuracy: 0.8935
```

In [45]:

```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(200, activation="relu"),
    keras.layers.Dense(100, activation="relu"),
    keras.layers.Dense(50, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
model.compile(loss="sparse_categorical_crossentropy",
              optimizer=keras.optimizers.SGD(lr=0.1),
              metrics=["accuracy"])
```

In [46]:

```
run_logdir = get_run_logdir()
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=100,
                    validation_data=(X_val, y_val),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.3012 - accuracy: 0.1124
- val_loss: 2.3017 - val_accuracy: 0.1064
Epoch 2/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2992 - accuracy: 0.1171
- val_loss: 2.2956 - val_accuracy: 0.1090
Epoch 3/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2897 - accuracy: 0.1301
- val_loss: 2.2850 - val_accuracy: 0.1460
Epoch 4/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2535 - accuracy: 0.1638
- val_loss: 2.2128 - val_accuracy: 0.1520
Epoch 5/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.2100 - accuracy: 0.1860
- val_loss: 2.2736 - val_accuracy: 0.2177
Epoch 6/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.1872 - accuracy: 0.1956
- val_loss: 2.4142 - val_accuracy: 0.1092
Epoch 7/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.1682 - accuracy: 0.2086
- val_loss: 1.9948 - val_accuracy: 0.3499
Epoch 8/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.1181 - accuracy: 0.2252
- val_loss: 2.0815 - val_accuracy: 0.1482
Epoch 9/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.1026 - accuracy: 0.2357
- val_loss: 2.0748 - val_accuracy: 0.2202
Epoch 10/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.0664 - accuracy: 0.2473
- val_loss: 1.9097 - val_accuracy: 0.3450
Epoch 11/100
1563/1563 [==============================] - 4s 3ms/step - loss: 2.0215 - accuracy: 0.2686
- val_loss: 2.9266 - val_accuracy: 0.1130
Epoch 12/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.9727 - accuracy: 0.2880
- val_loss: 2.4505 - val_accuracy: 0.1023
Epoch 13/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.9491 - accuracy: 0.3021
- val_loss: 1.7699 - val_accuracy: 0.3761
```

```
Epoch 14/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.9106 - accuracy: 0.3101
- val_loss: 1.8195 - val_accuracy: 0.2772
Epoch 15/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.8459 - accuracy: 0.3372
- val_loss: 1.5994 - val_accuracy: 0.4623
Epoch 16/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.7844 - accuracy: 0.3584
- val_loss: 1.5677 - val_accuracy: 0.4209
Epoch 17/100
1563/1563 [==============================] - 6s 4ms/step - loss: 1.7263 - accuracy: 0.3819
- val_loss: 1.4596 - val_accuracy: 0.4944
Epoch 18/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.6470 - accuracy: 0.4035
- val_loss: 1.6008 - val_accuracy: 0.4516
Epoch 19/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.5833 - accuracy: 0.4245
- val_loss: 1.7572 - val_accuracy: 0.3252
Epoch 20/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.5260 - accuracy: 0.4449
- val_loss: 1.4553 - val_accuracy: 0.4554
Epoch 21/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.4662 - accuracy: 0.4627
- val_loss: 1.9732 - val_accuracy: 0.2979
Epoch 22/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.4496 - accuracy: 0.4673
- val_loss: 1.2219 - val_accuracy: 0.5382
Epoch 23/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.4290 - accuracy: 0.4762
- val_loss: 1.6055 - val_accuracy: 0.3936
Epoch 24/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.4099 - accuracy: 0.4865
- val_loss: 1.2713 - val_accuracy: 0.4748
Epoch 25/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.3762 - accuracy: 0.4914
- val_loss: 1.6922 - val_accuracy: 0.4037
Epoch 26/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.3418 - accuracy: 0.5059
- val_loss: 1.3284 - val_accuracy: 0.4800
Epoch 27/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.3071 - accuracy: 0.5186
- val_loss: 1.1638 - val_accuracy: 0.5674
Epoch 28/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.2690 - accuracy: 0.5312
- val_loss: 2.2703 - val_accuracy: 0.3128
Epoch 29/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.2346 - accuracy: 0.5411
- val_loss: 1.1020 - val_accuracy: 0.5943
Epoch 30/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.1927 - accuracy: 0.5630
- val_loss: 1.2069 - val_accuracy: 0.5733
Epoch 31/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.1459 - accuracy: 0.5762
- val_loss: 1.0823 - val_accuracy: 0.5968
Epoch 32/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.1239 - accuracy: 0.5871
- val_loss: 1.3511 - val_accuracy: 0.5034
Epoch 33/100
1563/1563 [==============================] - 4s 3ms/step - loss: 1.0910 - accuracy: 0.6001
- val_loss: 1.5412 - val_accuracy: 0.4858
Epoch 34/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.0671 - accuracy: 0.6101
- val_loss: 0.7413 - val_accuracy: 0.7535
Epoch 35/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.0401 - accuracy: 0.6192
- val_loss: 1.0303 - val_accuracy: 0.6025
```

```
Epoch 36/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.0120 - accuracy: 0.6305
- val_loss: 0.9294 - val_accuracy: 0.6737
Epoch 37/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9970 - accuracy: 0.6400
- val_loss: 0.7515 - val_accuracy: 0.7343
Epoch 38/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9666 - accuracy: 0.6495
- val_loss: 0.7617 - val_accuracy: 0.7225
Epoch 39/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9493 - accuracy: 0.6558
- val_loss: 1.5460 - val_accuracy: 0.4588
Epoch 40/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9293 - accuracy: 0.6657
- val_loss: 1.0651 - val_accuracy: 0.5929
Epoch 41/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9122 - accuracy: 0.6719
- val_loss: 0.6557 - val_accuracy: 0.7786
Epoch 42/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.9006 - accuracy: 0.6769
- val_loss: 0.6576 - val_accuracy: 0.7741
Epoch 43/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8713 - accuracy: 0.6870
- val_loss: 0.8558 - val_accuracy: 0.7048
Epoch 44/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8687 - accuracy: 0.6904
- val_loss: 0.9681 - val_accuracy: 0.6271
Epoch 45/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8502 - accuracy: 0.6957
- val_loss: 0.8487 - val_accuracy: 0.7084
Epoch 46/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.8306 - accuracy: 0.7019
- val_loss: 0.9085 - val_accuracy: 0.6589
Epoch 47/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.8201 - accuracy: 0.7087
- val_loss: 0.5867 - val_accuracy: 0.8073
Epoch 48/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.8010 - accuracy: 0.7166
- val_loss: 1.0491 - val_accuracy: 0.6565
Epoch 49/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7687 - accuracy: 0.7292
- val_loss: 0.9513 - val_accuracy: 0.6748
Epoch 50/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7674 - accuracy: 0.7304
- val_loss: 1.0399 - val_accuracy: 0.6337
Epoch 51/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7534 - accuracy: 0.7367
- val_loss: 0.6406 - val_accuracy: 0.7752
Epoch 52/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7432 - accuracy: 0.7404
- val_loss: 0.7431 - val_accuracy: 0.7360
Epoch 53/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7228 - accuracy: 0.7494
- val_loss: 0.6644 - val_accuracy: 0.7548
Epoch 54/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.7168 - accuracy: 0.7500
- val_loss: 0.5011 - val_accuracy: 0.8349
Epoch 55/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7048 - accuracy: 0.7557
- val_loss: 0.8168 - val_accuracy: 0.6976
Epoch 56/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6814 - accuracy: 0.7655
- val_loss: 0.7679 - val_accuracy: 0.7080
Epoch 57/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6870 - accuracy: 0.7636
- val_loss: 0.5310 - val_accuracy: 0.8253
```

```
Epoch 58/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6575 - accuracy: 0.7708
- val_loss: 0.6654 - val_accuracy: 0.7741
Epoch 59/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.6560 - accuracy: 0.7744
- val_loss: 0.5178 - val_accuracy: 0.8087
Epoch 60/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6463 - accuracy: 0.7754
- val_loss: 0.5767 - val_accuracy: 0.8050
Epoch 61/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6315 - accuracy: 0.7832
- val_loss: 0.5590 - val_accuracy: 0.8125
Epoch 62/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6278 - accuracy: 0.7824
- val_loss: 0.4487 - val_accuracy: 0.8488
Epoch 63/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6177 - accuracy: 0.7869
- val_loss: 0.7228 - val_accuracy: 0.7484
Epoch 64/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6109 - accuracy: 0.7912
- val_loss: 0.4366 - val_accuracy: 0.8500
Epoch 65/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6014 - accuracy: 0.7933
- val_loss: 0.5342 - val_accuracy: 0.8250
Epoch 66/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5923 - accuracy: 0.7970
- val_loss: 0.7389 - val_accuracy: 0.7336
Epoch 67/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5772 - accuracy: 0.8025
- val_loss: 0.7176 - val_accuracy: 0.7505
Epoch 68/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5774 - accuracy: 0.8006
- val_loss: 0.5153 - val_accuracy: 0.8180
Epoch 69/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5649 - accuracy: 0.8086
- val_loss: 0.4705 - val_accuracy: 0.8391
Epoch 70/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5622 - accuracy: 0.8073
- val_loss: 0.9640 - val_accuracy: 0.6785
Epoch 71/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5547 - accuracy: 0.8110
- val_loss: 0.5159 - val_accuracy: 0.8249
Epoch 72/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5411 - accuracy: 0.8159
- val_loss: 1.0306 - val_accuracy: 0.6435
Epoch 73/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5457 - accuracy: 0.8144
- val_loss: 0.4227 - val_accuracy: 0.8599
Epoch 74/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5302 - accuracy: 0.8209
- val_loss: 0.5990 - val_accuracy: 0.7991
Epoch 75/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5271 - accuracy: 0.8193
- val_loss: 0.3571 - val_accuracy: 0.8839
Epoch 76/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5207 - accuracy: 0.8217
- val_loss: 0.9341 - val_accuracy: 0.7077
Epoch 77/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5203 - accuracy: 0.8243
- val_loss: 0.6296 - val_accuracy: 0.7674
Epoch 78/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5036 - accuracy: 0.8295
- val_loss: 0.3880 - val_accuracy: 0.8771
Epoch 79/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5092 - accuracy: 0.8281
- val_loss: 0.6327 - val_accuracy: 0.7780
```

```
Epoch 80/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.5016 - accuracy: 0.8292
- val_loss: 0.3985 - val_accuracy: 0.8700
Epoch 81/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4918 - accuracy: 0.8355
- val_loss: 0.3783 - val_accuracy: 0.8791
Epoch 82/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4897 - accuracy: 0.8358
- val_loss: 0.3636 - val_accuracy: 0.8814
Epoch 83/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4823 - accuracy: 0.8368
- val_loss: 0.6733 - val_accuracy: 0.7851
Epoch 84/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4808 - accuracy: 0.8378
- val_loss: 0.3948 - val_accuracy: 0.8707
Epoch 85/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4731 - accuracy: 0.8392
- val_loss: 0.3755 - val_accuracy: 0.8745
Epoch 86/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4633 - accuracy: 0.8429
- val_loss: 0.3788 - val_accuracy: 0.8777
Epoch 87/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4625 - accuracy: 0.8458
- val_loss: 0.4499 - val_accuracy: 0.8559
Epoch 88/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4600 - accuracy: 0.8452
- val_loss: 0.4726 - val_accuracy: 0.8478
Epoch 89/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4514 - accuracy: 0.8498
- val_loss: 0.4477 - val_accuracy: 0.8574
Epoch 90/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4443 - accuracy: 0.8508
- val_loss: 0.4367 - val_accuracy: 0.8482
Epoch 91/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4383 - accuracy: 0.8539
- val_loss: 0.5910 - val_accuracy: 0.8055
Epoch 92/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4595 - accuracy: 0.8483
- val_loss: 0.4648 - val_accuracy: 0.8410
Epoch 93/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4416 - accuracy: 0.8508
- val_loss: 0.3902 - val_accuracy: 0.8725
Epoch 94/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4317 - accuracy: 0.8542
- val_loss: 0.3076 - val_accuracy: 0.9013
Epoch 95/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4275 - accuracy: 0.8574
- val_loss: 0.6353 - val_accuracy: 0.7838
Epoch 96/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4288 - accuracy: 0.8561
- val_loss: 0.5652 - val_accuracy: 0.8004
Epoch 97/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4210 - accuracy: 0.8597
- val_loss: 0.3618 - val_accuracy: 0.8801
Epoch 98/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4166 - accuracy: 0.8606
- val_loss: 1.0170 - val_accuracy: 0.6729
Epoch 99/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4115 - accuracy: 0.8620
- val_loss: 0.6479 - val_accuracy: 0.7839
Epoch 100/100
1563/1563 [==============================] - 4s 3ms/step - loss: 0.4131 - accuracy: 0.8621
- val_loss: 0.4613 - val_accuracy: 0.8498
```

In [47]:

```
model = keras.models.Sequential([
```

```
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(300, activation="relu"),
    keras.layers.Dense(200, activation="relu"),
    keras.layers.Dense(50, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
model.compile(loss="sparse_categorical_crossentropy",
              optimizer=keras.optimizers.SGD(lr=0.05),
              metrics=["accuracy"])
run_logdir = get_run_logdir()
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=100,
                    validation_data=(X_val, y_val),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/100
1563/1563 [==============================] - 6s 4ms/step - loss: 2.2997 - accuracy: 0.1141
- val_loss: 2.2991 - val_accuracy: 0.1064
Epoch 2/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2970 - accuracy: 0.1211
- val_loss: 2.2947 - val_accuracy: 0.1064
Epoch 3/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2909 - accuracy: 0.1326
- val_loss: 2.2855 - val_accuracy: 0.2386
Epoch 4/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2678 - accuracy: 0.1657
- val_loss: 2.2532 - val_accuracy: 0.0971
Epoch 5/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.2003 - accuracy: 0.1897
- val_loss: 2.5754 - val_accuracy: 0.1064
Epoch 6/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.1381 - accuracy: 0.2168
- val_loss: 2.3208 - val_accuracy: 0.1007
Epoch 7/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.0671 - accuracy: 0.2474
- val_loss: 1.8834 - val_accuracy: 0.3227
Epoch 8/100
1563/1563 [==============================] - 5s 3ms/step - loss: 2.0036 - accuracy: 0.2667
- val_loss: 2.2124 - val_accuracy: 0.1942
Epoch 9/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.9430 - accuracy: 0.2952
- val_loss: 1.6896 - val_accuracy: 0.3838
Epoch 10/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.8760 - accuracy: 0.3253
- val_loss: 2.0604 - val_accuracy: 0.2644
Epoch 11/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.8256 - accuracy: 0.3437
- val_loss: 1.8575 - val_accuracy: 0.2312
Epoch 12/100
1563/1563 [==============================] - 6s 4ms/step - loss: 1.7405 - accuracy: 0.3762
- val_loss: 1.5858 - val_accuracy: 0.3849
Epoch 13/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.6940 - accuracy: 0.3943
- val_loss: 2.0275 - val_accuracy: 0.2206
Epoch 14/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.6511 - accuracy: 0.4080
- val_loss: 1.1617 - val_accuracy: 0.6333
Epoch 15/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.5691 - accuracy: 0.4390
- val_loss: 1.1758 - val_accuracy: 0.6108
Epoch 16/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.5069 - accuracy: 0.4606
- val_loss: 1.7793 - val_accuracy: 0.3144
Epoch 17/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.5151 - accuracy: 0.4566
```

```
- val_loss: 1.5559 - val_accuracy: 0.4007
Epoch 18/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.4575 - accuracy: 0.4785
- val_loss: 1.6037 - val_accuracy: 0.3814
Epoch 19/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.3830 - accuracy: 0.5034
- val_loss: 0.9991 - val_accuracy: 0.6789
Epoch 20/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.3303 - accuracy: 0.5226
- val_loss: 2.3241 - val_accuracy: 0.2805
Epoch 21/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.2476 - accuracy: 0.5534
- val_loss: 0.9046 - val_accuracy: 0.6868
Epoch 22/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.1902 - accuracy: 0.5732
- val_loss: 0.9375 - val_accuracy: 0.6315
Epoch 23/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.1510 - accuracy: 0.5890
- val_loss: 0.7965 - val_accuracy: 0.7244
Epoch 24/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.1011 - accuracy: 0.6078
- val_loss: 1.4741 - val_accuracy: 0.4883
Epoch 25/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.0668 - accuracy: 0.6168
- val_loss: 0.8290 - val_accuracy: 0.6973
Epoch 26/100
1563/1563 [==============================] - 5s 3ms/step - loss: 1.0348 - accuracy: 0.6294
- val_loss: 0.7980 - val_accuracy: 0.7166
Epoch 27/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9845 - accuracy: 0.6495
- val_loss: 1.1791 - val_accuracy: 0.6036
Epoch 28/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.9484 - accuracy: 0.6619
- val_loss: 1.8256 - val_accuracy: 0.4159
Epoch 29/100
1563/1563 [==============================] - 5s 4ms/step - loss: 0.9127 - accuracy: 0.6785
- val_loss: 0.5765 - val_accuracy: 0.8332
Epoch 30/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.8958 - accuracy: 0.6846
- val_loss: 1.1575 - val_accuracy: 0.5647
Epoch 31/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.8566 - accuracy: 0.6964
- val_loss: 0.8488 - val_accuracy: 0.6854
Epoch 32/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.8339 - accuracy: 0.7089
- val_loss: 0.7089 - val_accuracy: 0.7607
Epoch 33/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.8004 - accuracy: 0.7198
- val_loss: 0.8035 - val_accuracy: 0.6860
Epoch 34/100
1563/1563 [==============================] - 6s 4ms/step - loss: 0.7822 - accuracy: 0.7267
- val_loss: 0.8610 - val_accuracy: 0.6813
Epoch 35/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7625 - accuracy: 0.7350
- val_loss: 1.0670 - val_accuracy: 0.6147
Epoch 36/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7316 - accuracy: 0.7446
- val_loss: 0.8090 - val_accuracy: 0.7021
Epoch 37/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7200 - accuracy: 0.7501
- val_loss: 0.4848 - val_accuracy: 0.8521
Epoch 38/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7068 - accuracy: 0.7577
- val_loss: 0.5240 - val_accuracy: 0.8331
Epoch 39/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.7051 - accuracy: 0.7587
```

```
- val_loss: 0.7827 - val_accuracy: 0.7185
Epoch 40/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6932 - accuracy: 0.7633
- val_loss: 0.5866 - val_accuracy: 0.8019
Epoch 41/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6630 - accuracy: 0.7709
- val_loss: 0.4429 - val_accuracy: 0.8566
Epoch 42/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6461 - accuracy: 0.7787
- val_loss: 1.3816 - val_accuracy: 0.5719
Epoch 43/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6257 - accuracy: 0.7845
- val_loss: 0.5945 - val_accuracy: 0.7957
Epoch 44/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6176 - accuracy: 0.7865
- val_loss: 0.7709 - val_accuracy: 0.7205
Epoch 45/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.6133 - accuracy: 0.7895
- val_loss: 0.9628 - val_accuracy: 0.6697
Epoch 46/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5960 - accuracy: 0.7947
- val_loss: 0.9394 - val_accuracy: 0.6915
Epoch 47/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5889 - accuracy: 0.7989
- val_loss: 1.0036 - val_accuracy: 0.6515
Epoch 48/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5817 - accuracy: 0.8029
- val_loss: 0.7804 - val_accuracy: 0.7101
Epoch 49/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5794 - accuracy: 0.8032
- val_loss: 0.4160 - val_accuracy: 0.8641
Epoch 50/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5573 - accuracy: 0.8107
- val_loss: 0.4516 - val_accuracy: 0.8392
Epoch 51/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5528 - accuracy: 0.8125
- val_loss: 0.5074 - val_accuracy: 0.8234
Epoch 52/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5269 - accuracy: 0.8210
- val_loss: 0.4965 - val_accuracy: 0.8365
Epoch 53/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5200 - accuracy: 0.8251
- val_loss: 0.8680 - val_accuracy: 0.7033
Epoch 54/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5257 - accuracy: 0.8219
- val_loss: 0.4333 - val_accuracy: 0.8468
Epoch 55/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5184 - accuracy: 0.8250
- val_loss: 0.8542 - val_accuracy: 0.7127
Epoch 56/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.5021 - accuracy: 0.8310
- val_loss: 0.4394 - val_accuracy: 0.8441
Epoch 57/100
1563/1563 [==============================] - 6s 4ms/step - loss: 0.5086 - accuracy: 0.8288
- val_loss: 0.3927 - val_accuracy: 0.8682
Epoch 58/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4950 - accuracy: 0.8331
- val_loss: 0.4467 - val_accuracy: 0.8555
Epoch 59/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4903 - accuracy: 0.8352
- val_loss: 0.4387 - val_accuracy: 0.8407
Epoch 60/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4825 - accuracy: 0.8382
- val_loss: 1.3002 - val_accuracy: 0.6516
Epoch 61/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4819 - accuracy: 0.8382
```

```
- val_loss: 0.3949 - val_accuracy: 0.8640
Epoch 62/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4662 - accuracy: 0.8442
- val_loss: 0.3793 - val_accuracy: 0.8791
Epoch 63/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4609 - accuracy: 0.8470
- val_loss: 0.5298 - val_accuracy: 0.8192
Epoch 64/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4592 - accuracy: 0.8463
- val_loss: 0.6006 - val_accuracy: 0.8036
Epoch 65/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4662 - accuracy: 0.8449
- val_loss: 0.4961 - val_accuracy: 0.8255
Epoch 66/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4444 - accuracy: 0.8525
- val_loss: 0.6276 - val_accuracy: 0.7808
Epoch 67/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4495 - accuracy: 0.8495
- val_loss: 0.4905 - val_accuracy: 0.8327
Epoch 68/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4396 - accuracy: 0.8536
- val_loss: 0.4214 - val_accuracy: 0.8645
Epoch 69/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4408 - accuracy: 0.8542
- val_loss: 0.6153 - val_accuracy: 0.7860
Epoch 70/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4271 - accuracy: 0.8571
- val_loss: 0.4141 - val_accuracy: 0.8586
Epoch 71/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4210 - accuracy: 0.8598
- val_loss: 0.4748 - val_accuracy: 0.8344
Epoch 72/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4232 - accuracy: 0.8585
- val_loss: 0.3382 - val_accuracy: 0.8917
Epoch 73/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4215 - accuracy: 0.8594
- val_loss: 0.3401 - val_accuracy: 0.8878
Epoch 74/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4215 - accuracy: 0.8601
- val_loss: 0.4982 - val_accuracy: 0.8241
Epoch 75/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4091 - accuracy: 0.8642
- val_loss: 0.3189 - val_accuracy: 0.8990
Epoch 76/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4090 - accuracy: 0.8628
- val_loss: 0.6706 - val_accuracy: 0.7730
Epoch 77/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4049 - accuracy: 0.8671
- val_loss: 0.3684 - val_accuracy: 0.8721
Epoch 78/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.4076 - accuracy: 0.8650
- val_loss: 0.4253 - val_accuracy: 0.8583
Epoch 79/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3973 - accuracy: 0.8679
- val_loss: 0.4528 - val_accuracy: 0.8402
Epoch 80/100
1563/1563 [==============================] - 6s 4ms/step - loss: 0.3926 - accuracy: 0.8701
- val_loss: 0.5019 - val_accuracy: 0.8233
Epoch 81/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3938 - accuracy: 0.8694
- val_loss: 0.3282 - val_accuracy: 0.8949
Epoch 82/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3862 - accuracy: 0.8725
- val_loss: 0.6536 - val_accuracy: 0.7815
Epoch 83/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3825 - accuracy: 0.8748
```

```
- val_loss: 0.5464 - val_accuracy: 0.8068
Epoch 84/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3845 - accuracy: 0.8739
- val_loss: 0.4157 - val_accuracy: 0.8551
Epoch 85/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3815 - accuracy: 0.8729
- val_loss: 0.3160 - val_accuracy: 0.8955
Epoch 86/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3745 - accuracy: 0.8767
- val_loss: 0.3606 - val_accuracy: 0.8898
Epoch 87/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3764 - accuracy: 0.8751
- val_loss: 0.3529 - val_accuracy: 0.8860
Epoch 88/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3736 - accuracy: 0.8766
- val_loss: 0.5151 - val_accuracy: 0.8275
Epoch 89/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3614 - accuracy: 0.8810
- val_loss: 0.4789 - val_accuracy: 0.8372
Epoch 90/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3663 - accuracy: 0.8792
- val_loss: 0.2889 - val_accuracy: 0.9078
Epoch 91/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3668 - accuracy: 0.8796
- val_loss: 0.3919 - val_accuracy: 0.8737
Epoch 92/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3609 - accuracy: 0.8820
- val_loss: 0.2608 - val_accuracy: 0.9156
Epoch 93/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3508 - accuracy: 0.8837
- val_loss: 0.2604 - val_accuracy: 0.9180
Epoch 94/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3486 - accuracy: 0.8846
- val_loss: 0.2875 - val_accuracy: 0.9042
Epoch 95/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3439 - accuracy: 0.8855
- val_loss: 0.3063 - val_accuracy: 0.8967
Epoch 96/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3467 - accuracy: 0.8843
- val_loss: 0.3288 - val_accuracy: 0.8940
Epoch 97/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3456 - accuracy: 0.8850
- val_loss: 0.5116 - val_accuracy: 0.8257
Epoch 98/100
1563/1563 [==============================] - 6s 4ms/step - loss: 0.3395 - accuracy: 0.8885
- val_loss: 0.6614 - val_accuracy: 0.7786
Epoch 99/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3333 - accuracy: 0.8922
- val_loss: 1.0675 - val_accuracy: 0.6786
Epoch 100/100
1563/1563 [==============================] - 5s 3ms/step - loss: 0.3389 - accuracy: 0.8868
- val_loss: 0.2632 - val_accuracy: 0.9162
```

In [49]:

```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=[28, 28]),
    keras.layers.Dense(500, activation="relu"),
    keras.layers.Dense(250, activation="relu"),
    keras.layers.Dense(125, activation="relu"),
    keras.layers.Dense(50, activation="relu"),
    keras.layers.Dense(10, activation="softmax")
])
model.compile(loss="sparse_categorical_crossentropy",
              optimizer=keras.optimizers.SGD(lr=0.05),
              metrics=["accuracy"])
run_logdir = get_run_logdir()
```

```
tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
history = model.fit(X_train, y_train, epochs=100,
                    validation_data=(X_val, y_val),
                    callbacks=[tensorboard_cb])
```

```
Epoch 1/100
1563/1563 [==============================] - 8s 5ms/step - loss: 2.2989 - accuracy: 0.1172
- val_loss: 2.2976 - val_accuracy: 0.2038
Epoch 2/100
1563/1563 [==============================] - 7s 5ms/step - loss: 2.2889 - accuracy: 0.1363
- val_loss: 2.2763 - val_accuracy: 0.1029
Epoch 3/100
 888/1563 [================>.............] - ETA: 2s - loss: 2.2650 - accuracy: 0.1528
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
/tmp/ipykernel_3270/2701839310.py in <module>
     12 run_logdir = get_run_logdir()
     13 tensorboard_cb = keras.callbacks.TensorBoard(run_logdir)
---> 14 history = model.fit(X_train, y_train, epochs=100,
     15                     validation_data=(X_val, y_val),
     16                     callbacks=[tensorboard_cb])

~/.local/lib/python3.9/site-packages/keras/utils/traceback_utils.py in error_handler(*arg
s, **kwargs)
     62     filtered_tb = None
     63     try:
---> 64       return fn(*args, **kwargs)
     65     except Exception as e:  # pylint: disable=broad-except
     66       filtered_tb = _process_traceback_frames(e.__traceback__)

~/.local/lib/python3.9/site-packages/keras/engine/training.py in fit(self, x, y, batch_siz
e, epochs, verbose, callbacks, validation_split, validation_data, shuffle, class_weight, s
ample_weight, initial_epoch, steps_per_epoch, validation_steps, validation_batch_size, val
idation_freq, max_queue_size, workers, use_multiprocessing)
   1214                 _r=1):
   1215               callbacks.on_train_batch_begin(step)
-> 1216               tmp_logs = self.train_function(iterator)
   1217               if data_handler.should_sync:
   1218                 context.async_wait()

~/.local/lib/python3.9/site-packages/tensorflow/python/util/traceback_utils.py in error_ha
ndler(*args, **kwargs)
    148     filtered_tb = None
    149     try:
--> 150       return fn(*args, **kwargs)
    151     except Exception as e:
    152       filtered_tb = _process_traceback_frames(e.__traceback__)

~/.local/lib/python3.9/site-packages/tensorflow/python/eager/def_function.py in __call__(s
elf, *args, **kwds)
    908
    909       with OptionalXlaContext(self._jit_compile):
--> 910         result = self._call(*args, **kwds)
    911
    912       new_tracing_count = self.experimental_get_tracing_count()

~/.local/lib/python3.9/site-packages/tensorflow/python/eager/def_function.py in _call(sel
f, *args, **kwds)
    940       # In this case we have created variables on the first call, so we run the
    941       # defunned version which is guaranteed to never create variables.
--> 942       return self._stateless_fn(*args, **kwds)  # pylint: disable=not-callable
    943     elif self._stateful_fn is not None:
    944       # Release the lock early so that multiple threads can perform the call

~/.local/lib/python3.9/site-packages/tensorflow/python/eager/function.py in __call__(self,
```

```
 *args, **kwargs)
   3128       (graph_function,
   3129        filtered_flat_args) = self._maybe_define_function(args, kwargs)
-> 3130     return graph_function._call_flat(
   3131         filtered_flat_args, captured_inputs=graph_function.captured_inputs)  # pyl
int: disable=protected-access
   3132

~/.local/lib/python3.9/site-packages/tensorflow/python/eager/function.py in _call_flat(sel
f, args, captured_inputs, cancellation_manager)
   1957         and executing_eagerly):
   1958       # No tape is watching; skip to running the function.
-> 1959       return self._build_call_outputs(self._inference_function.call(
   1960           ctx, args, cancellation_manager=cancellation_manager))
   1961     forward_backward = self._select_forward_and_backward_functions(

~/.local/lib/python3.9/site-packages/tensorflow/python/eager/function.py in call(self, ct
x, args, cancellation_manager)
    596       with _InterpolateFunctionError(self):
    597         if cancellation_manager is None:
--> 598           outputs = execute.execute(
    599               str(self.signature.name),
    600               num_outputs=self._num_outputs,

~/.local/lib/python3.9/site-packages/tensorflow/python/eager/execute.py in quick_execute(o
p_name, num_outputs, inputs, attrs, ctx, name)
     56   try:
     57     ctx.ensure_initialized()
---> 58     tensors = pywrap_tfe.TFE_Py_Execute(ctx._handle, device_name, op_name,
     59                                         inputs, attrs, num_outputs)
     60   except core._NotOkStatusException as e:

KeyboardInterrupt:
```