assignment-6-cnn-mnist-bc11

April 9, 2024

[ ]:
```python
from keras.datasets import fashion_mnist
(train_X,train_Y), (test_X,test_Y) = fashion_mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-
datasets/train-labels-idx1-ubyte.gz
29515/29515 [==============================] - 0s 1us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-
datasets/train-images-idx3-ubyte.gz
26421880/26421880 [==============================] - 2s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-
datasets/t10k-labels-idx1-ubyte.gz
5148/5148 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-
datasets/t10k-images-idx3-ubyte.gz
4422102/4422102 [==============================] - 1s 0us/step
```

[ ]:
```python
import numpy as np
from keras.utils import to_categorical
import matplotlib.pyplot as plt
%matplotlib inline

print('Training data shape : ', train_X.shape, train_Y.shape)

print('Testing data shape : ', test_X.shape, test_Y.shape)
```

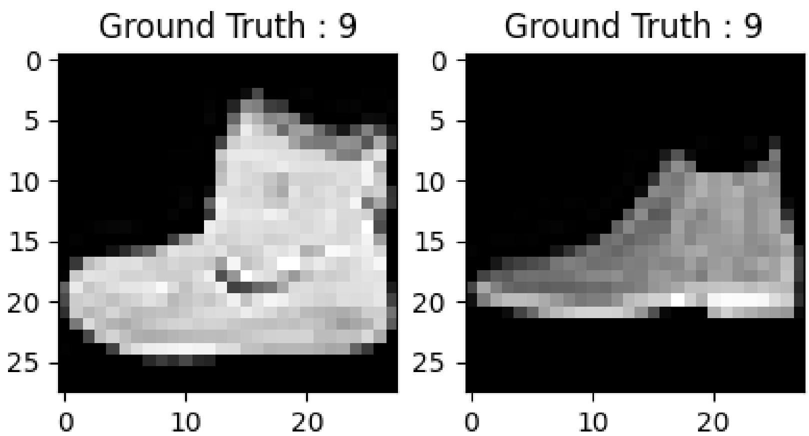
```
Training data shape :  (60000, 28, 28) (60000,)
Testing data shape :  (10000, 28, 28) (10000,)
```

[ ]:
```python
# Find the unique numbers from the train labels
classes = np.unique(train_Y)
nClasses = len(classes)
print('Total number of outputs : ', nClasses)
print('Output classes : ', classes)
```

```
Total number of outputs :  10
Output classes :  [0 1 2 3 4 5 6 7 8 9]
```

[ ]:
```
plt.figure(figsize=[5,5])

# Display the first image in training data
plt.subplot(121)
plt.imshow(train_X[0,:,:], cmap='gray')
plt.title("Ground Truth : {}".format(train_Y[0]))

# Display the first image in testing data
plt.subplot(122)
plt.imshow(test_X[0,:,:], cmap='gray')
plt.title("Ground Truth : {}".format(test_Y[0]))
```

[ ]:
```
Text(0.5, 1.0, 'Ground Truth : 9')
```



[ ]:
```
train_X = train_X.reshape(-1, 28,28, 1)
test_X = test_X.reshape(-1, 28,28, 1)
train_X.shape, test_X.shape
```

[ ]:
```
((60000, 28, 28, 1), (10000, 28, 28, 1))
```

[ ]:
```
train_X = train_X.astype('float32')
test_X = test_X.astype('float32')
train_X = train_X / 255.
test_X = test_X / 255.
```

[ ]:
```
# Change the labels from categorical to one-hot encoding
train_Y_one_hot = to_categorical(train_Y)
test_Y_one_hot = to_categorical(test_Y)

# Display the change for category label using one-hot encoding
print('Original label:', train_Y[0])
```

```
print('After conversion to one-hot:', train_Y_one_hot[0])
```

```
Original label: 9
After conversion to one-hot: [0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
```

[ ]:
```
from sklearn.model_selection import train_test_split
train_X,valid_X,train_label,valid_label = train_test_split(train_X,␣
↪train_Y_one_hot, test_size=0.2, random_state=13)
```

[ ]:
```
train_X.shape,valid_X.shape,train_label.shape,valid_label.shape
```

[ ]:
```
((48000, 28, 28, 1), (12000, 28, 28, 1), (48000, 10), (12000, 10))
```

https://www.datacamp.com/tutorial/convolutional-neural-networks-python

[ ]:
```

```

[ ]:
```
!pip install keras
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-
wheels/public/simple/
Requirement already satisfied: keras in /usr/local/lib/python3.9/dist-packages
(2.12.0)
```

[ ]:
```
import keras
from keras.models import Sequential
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from tensorflow.keras.layers import BatchNormalization
#from keras.layers.normalization import BatchNormalization
#from keras.layers.advanced_activations import LeakyReLU
from keras.layers import LeakyReLU
```

[ ]:
```
#from keras.models import Input
from keras.models import Model
```

[ ]:
```
batch_size = 64
epochs = 20
num_classes = 10
```

[ ]:
```
fashion_model = Sequential()
fashion_model.add(Conv2D(32, kernel_size=(3,␣
↪3),activation='linear',input_shape=(28,28,1),padding='same'))
fashion_model.add(LeakyReLU(alpha=0.1))
fashion_model.add(MaxPooling2D((2, 2),padding='same'))
fashion_model.add(Conv2D(64, (3, 3), activation='linear',padding='same'))
fashion_model.add(LeakyReLU(alpha=0.1))
```

```
fashion_model.add(MaxPooling2D(pool_size=(2, 2),padding='same'))
fashion_model.add(Conv2D(128, (3, 3), activation='linear',padding='same'))
fashion_model.add(LeakyReLU(alpha=0.1))
fashion_model.add(MaxPooling2D(pool_size=(2, 2),padding='same'))
fashion_model.add(Flatten())
fashion_model.add(Dense(128, activation='linear'))
fashion_model.add(LeakyReLU(alpha=0.1))
fashion_model.add(Dense(num_classes, activation='softmax'))
```

[ ]:
```
fashion_model.compile(loss=keras.losses.categorical_crossentropy,␣
 ↪optimizer=keras.optimizers.Adam(),metrics=['accuracy'])
```

[ ]:
```
fashion_model.summary()
```

```
Model: "sequential"

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 32)        320

 leaky_re_lu (LeakyReLU)     (None, 28, 28, 32)        0

 max_pooling2d (MaxPooling2D  (None, 14, 14, 32)       0
 )

 conv2d_1 (Conv2D)           (None, 14, 14, 64)        18496

 leaky_re_lu_1 (LeakyReLU)   (None, 14, 14, 64)        0

 max_pooling2d_1 (MaxPooling  (None, 7, 7, 64)         0
 2D)

 conv2d_2 (Conv2D)           (None, 7, 7, 128)         73856

 leaky_re_lu_2 (LeakyReLU)   (None, 7, 7, 128)         0

 max_pooling2d_2 (MaxPooling  (None, 4, 4, 128)        0
 2D)

 flatten (Flatten)           (None, 2048)              0

 dense (Dense)               (None, 128)               262272

 leaky_re_lu_3 (LeakyReLU)   (None, 128)               0

 dense_1 (Dense)             (None, 10)                1290
```

```
=================================================================
Total params: 356,234
Trainable params: 356,234
Non-trainable params: 0
_________________________________________________________________
```

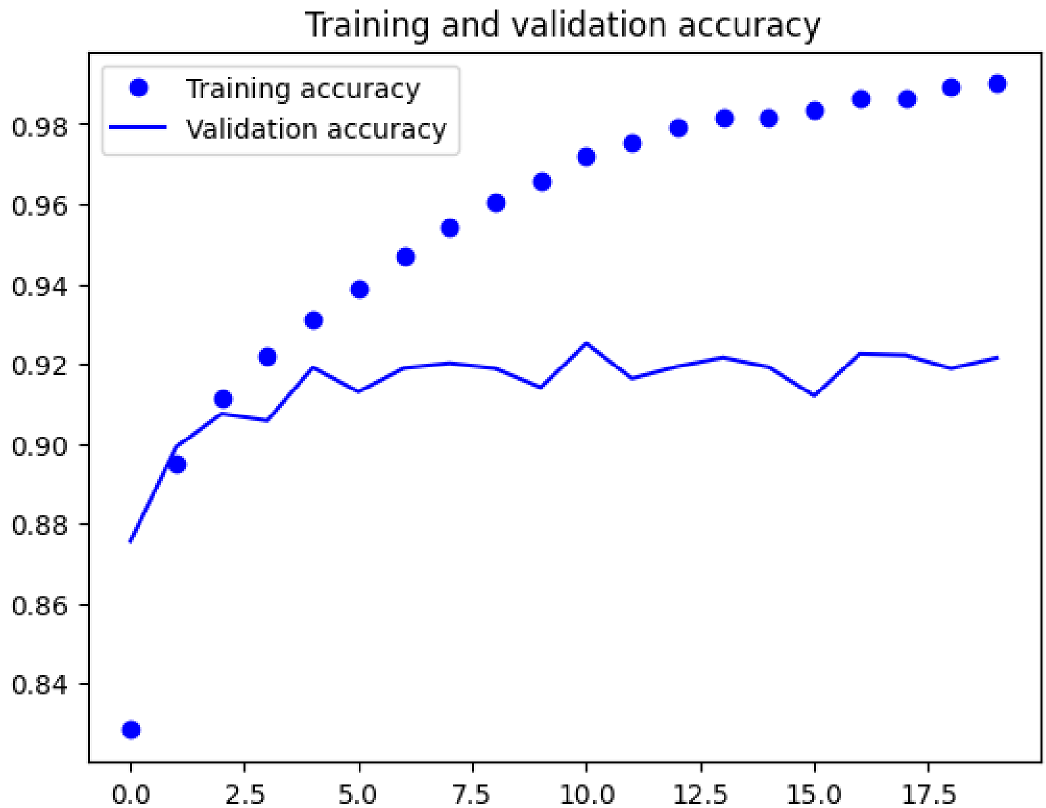
[ ]:
```
fashion_train = fashion_model.fit(train_X, train_label,␣
↪batch_size=batch_size,epochs=epochs,verbose=1,validation_data=(valid_X,␣
↪valid_label))
```

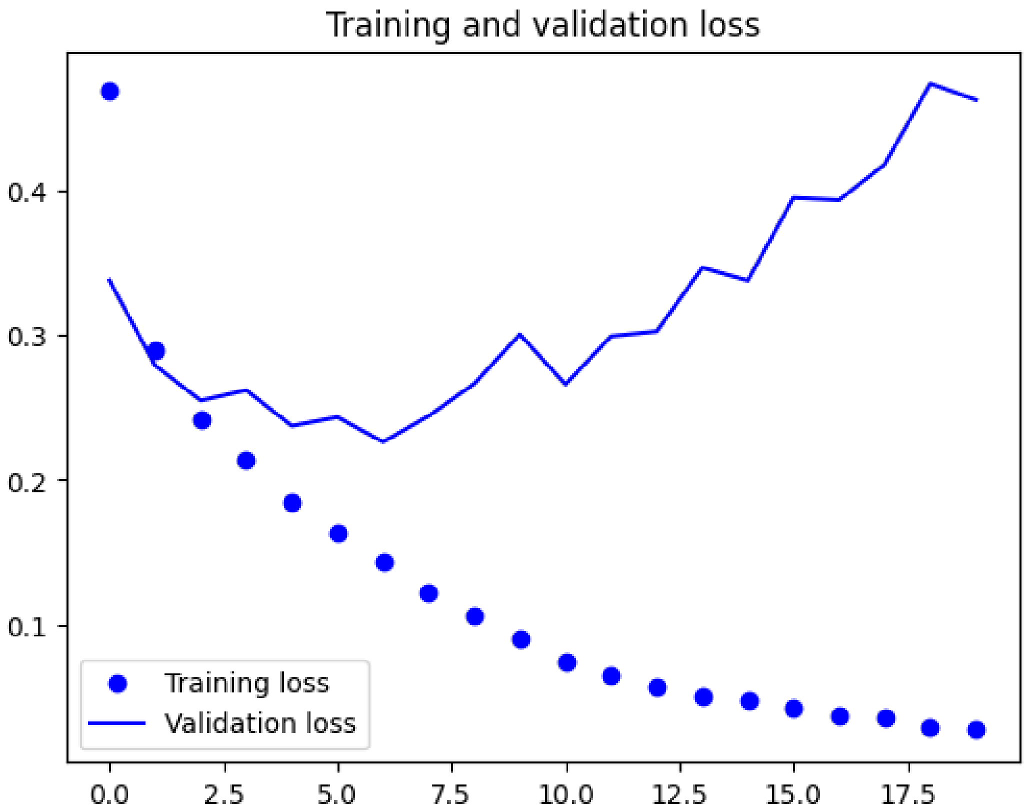
[ ]:
```
test_eval = fashion_model.evaluate(test_X, test_Y_one_hot, verbose=0)
```

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

```
Test loss: 0.4764760136604309
Test accuracy: 0.9204000234603882
```

[ ]:
```
accuracy = fashion_train.history['accuracy']
val_accuracy = fashion_train.history['val_accuracy']
loss = fashion_train.history['loss']
val_loss = fashion_train.history['val_loss']
epochs = range(len(accuracy))
plt.plot(epochs, accuracy, 'bo', label='Training accuracy')
plt.plot(epochs, val_accuracy, 'b', label='Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend()
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```


Training and validation accuracy
Training accuracy
Validation accuracy
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5



Adding Dropout into the Network

```
[ ]: batch_size = 64
     epochs = 20
     num_classes = 10
```

```
[ ]: fashion_model = Sequential()
     fashion_model.add(Conv2D(32, kernel_size=(3,␣
      ↪3),activation='linear',padding='same',input_shape=(28,28,1)))
     fashion_model.add(LeakyReLU(alpha=0.1))
     fashion_model.add(MaxPooling2D((2, 2),padding='same'))
     fashion_model.add(Dropout(0.25))
     fashion_model.add(Conv2D(64, (3, 3), activation='linear',padding='same'))
     fashion_model.add(LeakyReLU(alpha=0.1))
     fashion_model.add(MaxPooling2D(pool_size=(2, 2),padding='same'))
     fashion_model.add(Dropout(0.25))
     fashion_model.add(Conv2D(128, (3, 3), activation='linear',padding='same'))
     fashion_model.add(LeakyReLU(alpha=0.1))
     fashion_model.add(MaxPooling2D(pool_size=(2, 2),padding='same'))
     fashion_model.add(Dropout(0.4))
     fashion_model.add(Flatten())
```

```python
fashion_model.add(Dense(128, activation='linear'))
fashion_model.add(LeakyReLU(alpha=0.1))
fashion_model.add(Dropout(0.3))
fashion_model.add(Dense(num_classes, activation='softmax'))
```

[ ]:
```python
fashion_model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_3 (Conv2D)           (None, 28, 28, 32)        320

 leaky_re_lu_4 (LeakyReLU)   (None, 28, 28, 32)        0

 max_pooling2d_3 (MaxPooling  (None, 14, 14, 32)       0
 2D)

 dropout (Dropout)           (None, 14, 14, 32)        0

 conv2d_4 (Conv2D)           (None, 14, 14, 64)        18496

 leaky_re_lu_5 (LeakyReLU)   (None, 14, 14, 64)        0

 max_pooling2d_4 (MaxPooling  (None, 7, 7, 64)         0
 2D)

 dropout_1 (Dropout)         (None, 7, 7, 64)          0

 conv2d_5 (Conv2D)           (None, 7, 7, 128)         73856

 leaky_re_lu_6 (LeakyReLU)   (None, 7, 7, 128)         0

 max_pooling2d_5 (MaxPooling  (None, 4, 4, 128)        0
 2D)

 dropout_2 (Dropout)         (None, 4, 4, 128)         0

 flatten_1 (Flatten)         (None, 2048)              0

 dense_2 (Dense)             (None, 128)               262272

 leaky_re_lu_7 (LeakyReLU)   (None, 128)               0

 dropout_3 (Dropout)         (None, 128)               0

 dense_3 (Dense)             (None, 10)                1290
```

```
=================================================================
Total params: 356,234
Trainable params: 356,234
Non-trainable params: 0
_________________________________________________________________
```

[ ]:
```
fashion_model.compile(loss=keras.losses.categorical_crossentropy,␣
↪optimizer=keras.optimizers.Adam(),metrics=['accuracy'])
```

[ ]:
```
fashion_train_dropout = fashion_model.fit(train_X, train_label,␣
↪batch_size=batch_size,epochs=epochs,verbose=1,validation_data=(valid_X,␣
↪valid_label))
```

[ ]:
```
fashion_model.save("fashion_model_dropout.h5py")
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op,
_jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing
3 of 3). These functions will not be directly callable after loading.
```

[ ]:
```
test_eval = fashion_model.evaluate(test_X, test_Y_one_hot, verbose=1)
```

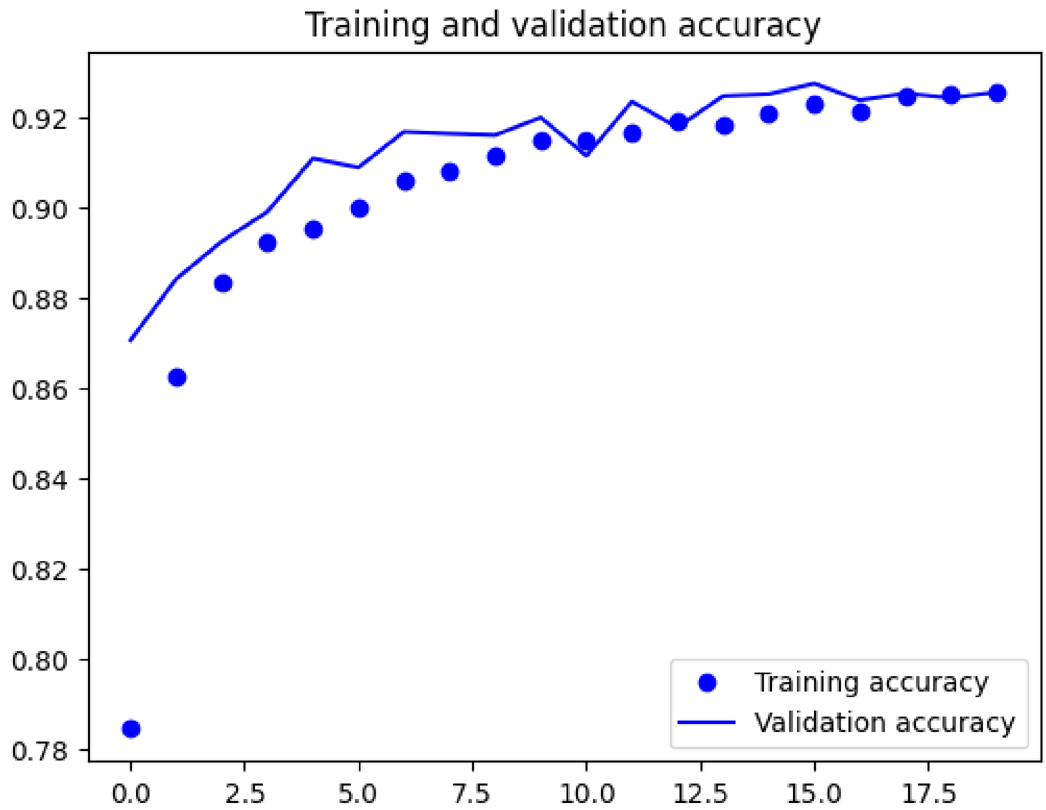
```
313/313 [==============================] - 1s 3ms/step - loss: 0.2202 -
accuracy: 0.9213
```

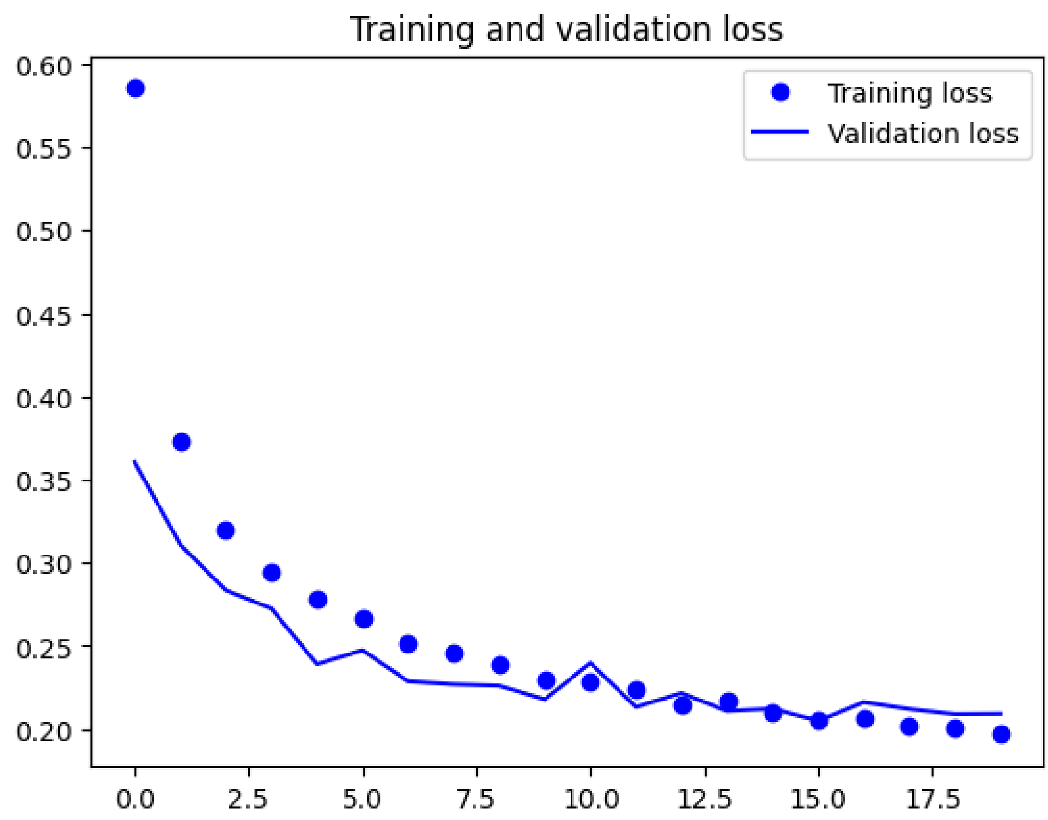
[ ]:
```

```

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

```
Test loss: 0.22022153437137604
Test accuracy: 0.9212999939918518
```

[ ]:
```
accuracy = fashion_train_dropout.history['accuracy']
val_accuracy = fashion_train_dropout.history['val_accuracy']
loss = fashion_train_dropout.history['loss']
val_loss = fashion_train_dropout.history['val_loss']
epochs = range(len(accuracy))
plt.plot(epochs, accuracy, 'bo', label='Training accuracy')
plt.plot(epochs, val_accuracy, 'b', label='Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend()
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```


Training and validation accuracy
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Training accuracy
Validation accuracy




```
[ ]: predicted_classes = fashion_model.predict(test_X)
```

```
313/313 [==============================] - 1s 2ms/step
```

```
[ ]: predicted_classes = np.argmax(np.round(predicted_classes),axis=1)
```

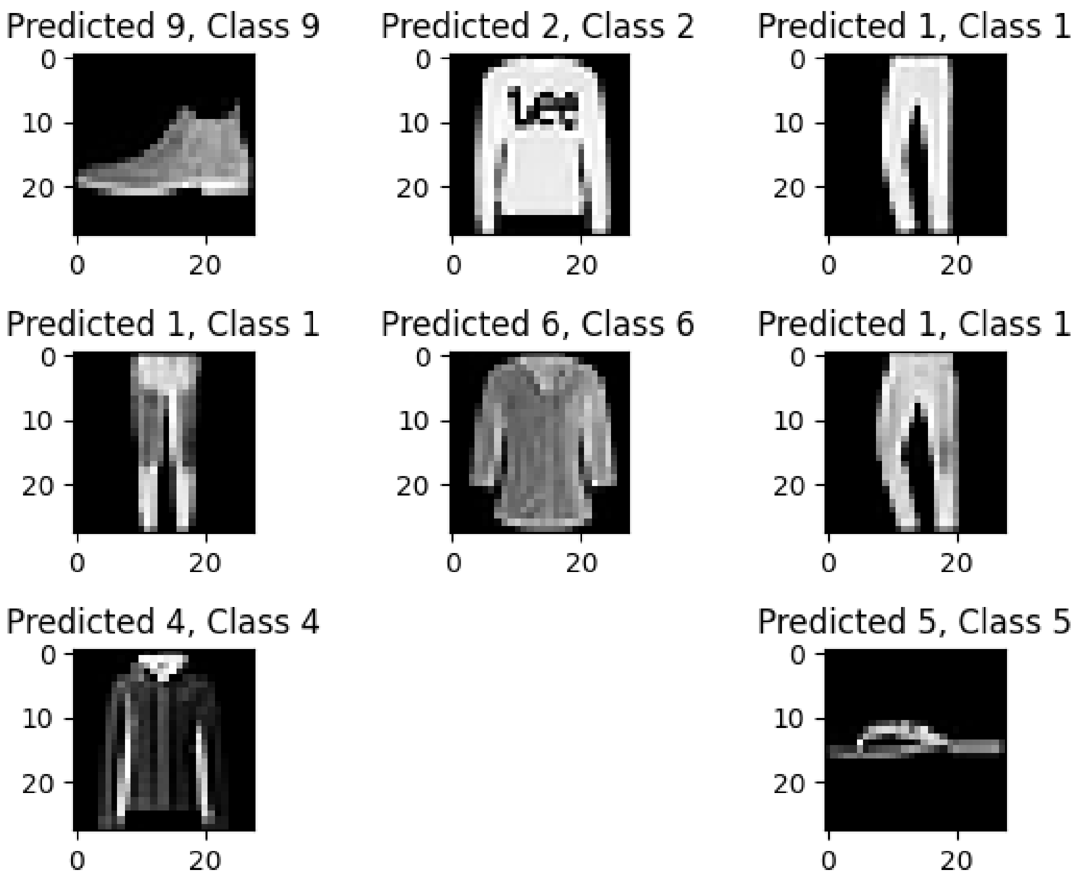
```
[ ]: predicted_classes.shape, test_Y.shape
```

```
[ ]: ((10000,), (10000,))
```

```
[ ]: correct = np.where(predicted_classes==test_Y)[0]
print("Found %d correct labels" % len(correct))
for i, correct in enumerate(correct[:9]):
    plt.subplot(3,3,i+1)
    plt.imshow(test_X[correct].reshape(28,28), cmap='gray',␣
 ↪interpolation='none')
    plt.title("Predicted {}, Class {}".format(predicted_classes[correct],␣
 ↪test_Y[correct]))
    plt.tight_layout()
```

```
Found 9176 correct labels
```

```
<ipython-input-37-0178221d62f4>:4: MatplotlibDeprecationWarning: Auto-removal of
overlapping axes is deprecated since 3.6 and will be removed two minor releases
later; explicitly call ax.remove() as needed.
  plt.subplot(3,3,i+1)
```

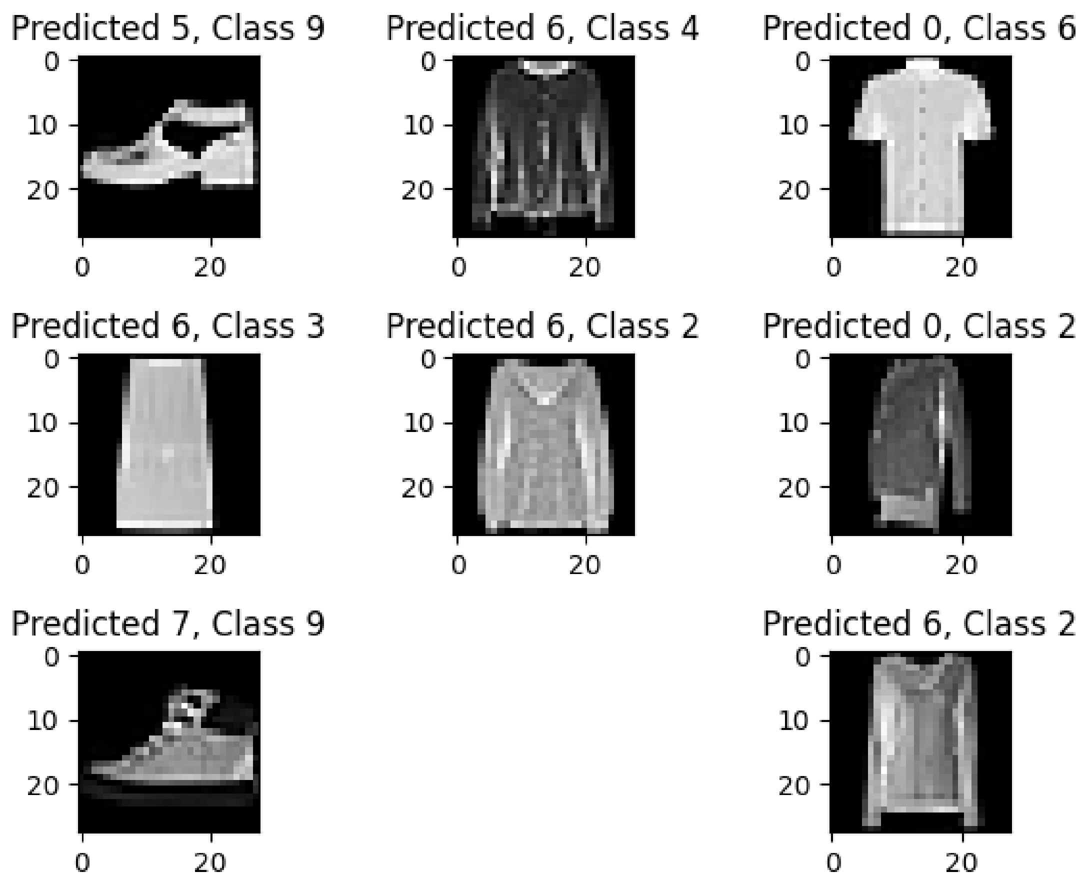


[ ]:
```
incorrect = np.where(predicted_classes!=test_Y)[0]
print("Found %d incorrect labels" % len(incorrect))
for i, incorrect in enumerate(incorrect[:9]):
    plt.subplot(3,3,i+1)
    plt.imshow(test_X[incorrect].reshape(28,28), cmap='gray',␣
 ↪interpolation='none')
    plt.title("Predicted {}, Class {}".format(predicted_classes[incorrect],␣
 ↪test_Y[incorrect]))
    plt.tight_layout()
```

```
Found 824 incorrect labels
```

```
<ipython-input-38-0bf9e7d6e015>:4: MatplotlibDeprecationWarning: Auto-removal of
overlapping axes is deprecated since 3.6 and will be removed two minor releases
later; explicitly call ax.remove() as needed.
```

```
plt.subplot(3,3,i+1)
```



[ ]:
```python
from sklearn.metrics import classification_report
target_names = ["Class {}".format(i) for i in range(num_classes)]
print(classification_report(test_Y, predicted_classes,␣
↪target_names=target_names))
```

```
              precision    recall  f1-score   support

     Class 0       0.79      0.89      0.84      1000
     Class 1       0.99      0.98      0.99      1000
     Class 2       0.93      0.81      0.87      1000
     Class 3       0.93      0.91      0.92      1000
     Class 4       0.86      0.89      0.87      1000
     Class 5       0.99      0.99      0.99      1000
     Class 6       0.77      0.77      0.77      1000
     Class 7       0.96      0.98      0.97      1000
     Class 8       0.99      0.99      0.99      1000
     Class 9       0.98      0.96      0.97      1000
```

```
    accuracy                           0.92     10000
   macro avg       0.92      0.92      0.92     10000
weighted avg       0.92      0.92      0.92     10000
```