# import library

In [2]:
```
import tensorflow
from tensorflow.keras.datasets import mnist
```

In [6]:
```
#load MNIST dataset
(x_train,y_train),(x_test,y_test)=mnist.load_data()
```

In [8]:
```
print(x_train.shape)
```

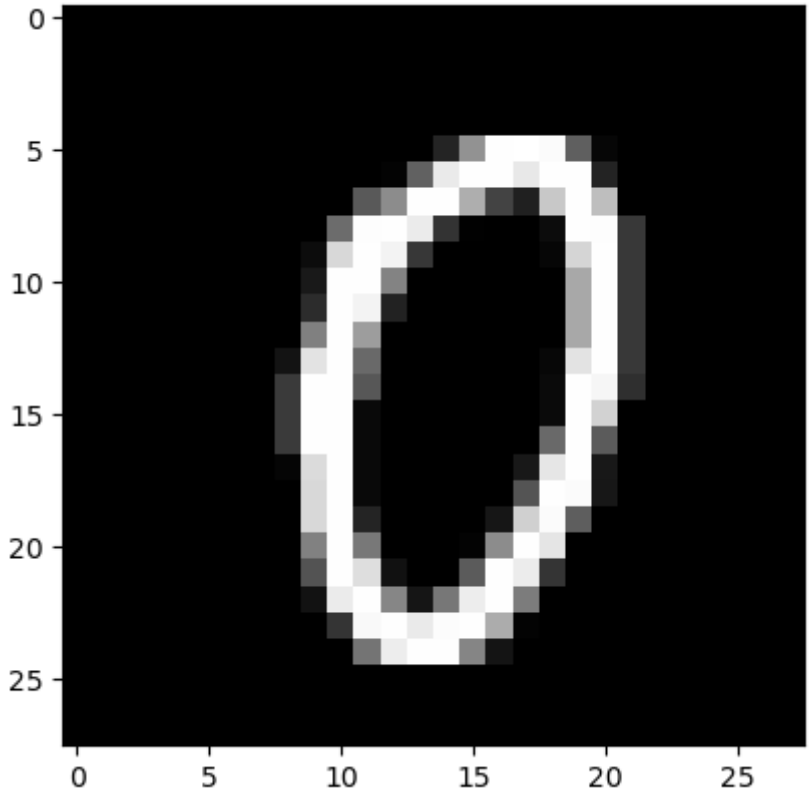
```
(60000, 28, 28)
```

In [9]:
```
x_train[0].shape
```

Out[9]:
```
(28, 28)
```

In [10]:
```
from matplotlib import pyplot as plt
```

In [11]:
```
plt.imshow(x_train[1000])
plt.gray()
plt.show()
```




In [12]:
```
from tensorflow.keras.layers import Dense, Flatten, Dropout
from tensorflow.keras.layers import Conv2D, MaxPooling2D
from tensorflow.keras.models import Sequential
from tensorflow.keras.utils import to_categorical
from tensorflow.keras import backend as k
```

In [13]:
```
k.set_image_data_format('channels_last')
```

In [14]:
```
#set image information
channels=1
height=28
width=28
```

In [15]:
```
x_train.shape
```

Out[15]: (60000, 28, 28)

In [16]:
```
x_train
```

Out[16]:
```
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]]], dtype=uint8)
```

In [19]:
```
train_data=x_train.reshape(x_train.shape[0],height,width,channels)
```

In [20]:
```
train_data.shape
```

Out[20]:
```
(60000, 28, 28, 1)
```

In [21]:
```
test_data=x_test.reshape(x_test.shape[0],height,width,channels)
```

In [22]:
```
test_data.shape
```

Out[22]:
```
(10000, 28, 28, 1)
```

In [23]:
```
x_train.max()
```

Out[23]:
```
255
```

In [24]:
```
# scale the data
train_data=train_data/255
test_data=test_data/255
```

In [25]:
```
train_data.max()
```

Out[25]:
```
1.0
```

In [26]:
```
# one hot encoding outcome
train_target=to_categorical(y_train)
test_target=to_categorical(y_test)
```

In [27]:
```
#number of classes
number_of_classes=test_target.shape[1]
```

In [28]:
```
#model building
model=Sequential()
model.add(Conv2D(filters=64,kernel_size=(5,5),input_shape=(width,height,channels),activation='relu'))
```

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

model.add(Conv2D(filters=32,kernel_size=(5,5),activation="relu"))
model.add(MaxPooling2D(pool_size=(2,2)))

model.add(Flatten())

model.add(Dense(128,activation="relu"))

model.add(Dense(number_of_classes,activation="softmax"))
```

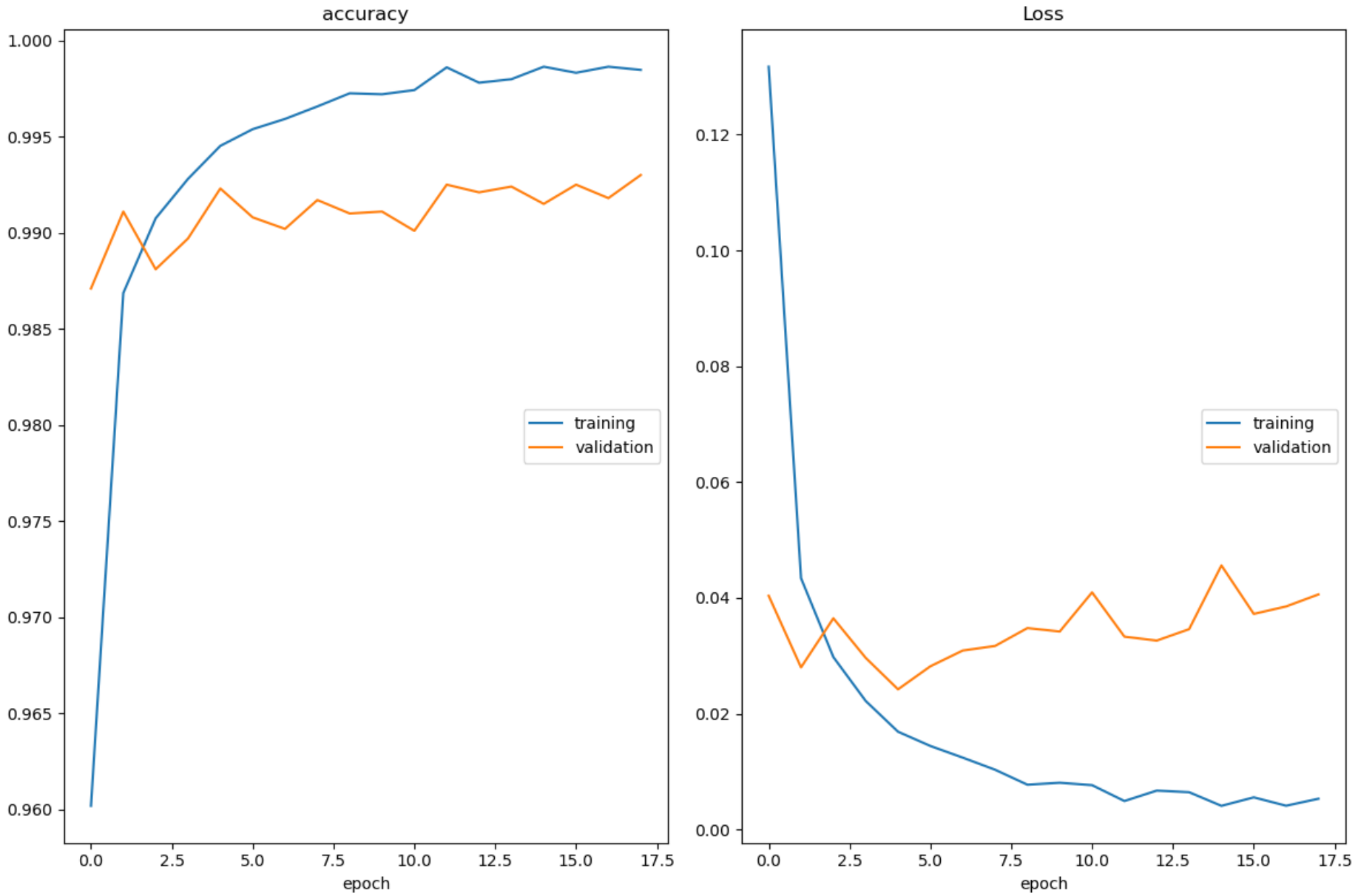
In [29]:
```
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                 Output Shape              Param #
=================================================================
 conv2d (Conv2D)              (None, 24, 24, 64)        1664

 max_pooling2d (MaxPooling2D  (None, 12, 12, 64)       0
 )

 conv2d_1 (Conv2D)            (None, 8, 8, 32)          51232

 max_pooling2d_1 (MaxPooling  (None, 4, 4, 32)         0
 2D)

 flatten (Flatten)            (None, 512)               0

 dense_3 (Dense)              (None, 128)               65664

 dense_4 (Dense)              (None, 10)                1290

=================================================================
Total params: 119,850
Trainable params: 119,850
Non-trainable params: 0
_________________________________________________________________
```

In [30]:
```
#compile the model
model.compile(loss="categorical_crossentropy",optimizer='adam',metrics=['accuracy'])
```

In [31]:
```
from livelossplot import PlotLossesKerasTF
```

In [32]:
```
#train the model
res=model.fit(train_data,train_target,epochs=18,validation_data=(test_data,test_target),callbacks=[PlotLossesKerasTF()])
```



```
accuracy
        training                (min:    0.960, max:    0.999, cur:    0.998)
        validation              (min:    0.987, max:    0.993, cur:    0.993)
Loss
        training                (min:    0.004, max:    0.132, cur:    0.005)
        validation              (min:    0.024, max:    0.046, cur:    0.041)
1875/1875 [==============================] - 274s 146ms/step - loss: 0.0053 - accuracy: 0.9985 - val_loss: 0.0406 - val_accurac
y: 0.9930
```

In [ ]: