MNIST Handwritten Digits Dataset

In [ ]:
```
import tensorflow
from tensorflow import keras
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Dense,Flatten
```

In [3]:
```
(X_train,y_train),(X_test,y_test) = keras.datasets.mnist.load_data()
```

In [4]:
```
X_test.shape
```

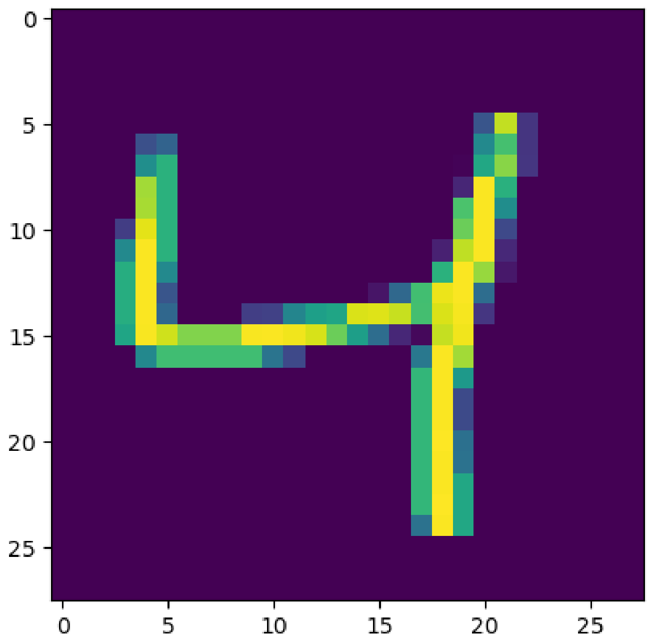
Out[4]:
```
(10000, 28, 28)
```

In [5]:
```
y_train
```

Out[5]:
```
array([5, 0, 4, ..., 5, 6, 8], dtype=uint8)
```

In [6]:
```
import matplotlib.pyplot as plt
plt.imshow(X_train[2])
```

Out[6]:
```
<matplotlib.image.AxesImage at 0x180aed5a050>
```



In [8]:
```
X_train=X_train/255
X_test=X_test/255
```

In [9]:
```
X_train[0]
```

```
Out[9]: array([[0.        , 0.        , 0.        , 0.        , 0.        ,
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         0.65098039, 1.        , 0.96862745, 0.49803922, 0.        ,
         0.        , 0.        , 0.        ],
        [0.        , 0.        , 0.        , 0.        , 0.        ,
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         0.99215686, 0.99215686, 0.99215686, 0.88235294, 0.6745098 ,
         0.99215686, 0.94901961, 0.76470588, 0.25098039, 0.        ,
         0.        , 0.        , 0.        ],
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         0.99215686, 0.99215686, 0.99215686, 0.99215686, 0.99215686,
         0.99215686, 0.99215686, 0.98431373, 0.36470588, 0.32156863,
         0.32156863, 0.21960784, 0.15294118, 0.        , 0.        ,
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         0.71372549, 0.96862745, 0.94509804, 0.        , 0.        ,
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         0.        , 0.        , 0.        ],
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         0.        , 0.        , 0.        , 0.        , 0.        ,
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         0.        , 0.        , 0.        , 0.        , 0.05490196,
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         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        ],
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         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.04313725, 0.74509804, 0.99215686, 0.2745098 ,
```

```
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  0.77647059, 0.31764706, 0.00784314, 0.        , 0.        ,
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  0.        , 0.        , 0.        ],
```

```
        [0.        , 0.        , 0.        , 0.        , 0.        ,
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         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        ],
        [0.        , 0.        , 0.        , 0.        , 0.        ,
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         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        ]])
```

In [15]:
```
model=Sequential()
model.add(Flatten(input_shape=(28,28)))
model.add(Dense(128,activation='relu'))
model.add(Dense(32,activation='relu'))
model.add(Dense(10,activation='softmax'))
```

In [16]:
```
model.summary()
```

Model: "sequential_5"

Layer (type)	**Output Shape**	**Param #**
flatten_3 (Flatten)	(None, 784)	0
dense_9 (Dense)	(None, 128)	100,480
dense_10 (Dense)	(None, 32)	4,128
dense_11 (Dense)	(None, 10)	330

Total params: 104,938 (409.91 KB)

Trainable params: 104,938 (409.91 KB)

Non-trainable params: 0 (0.00 B)

In [17]:
```
model.compile(loss='sparse_categorical_crossentropy',optimizer='Adam',metrics=['accuracy'])
```

In [18]:
```
history=model.fit(X_train,y_train,epochs=25,validation_split=0.2)
```

```
Epoch 1/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 6s 3ms/step - accuracy: 0.8542 - loss: 0.4945 - val_accuracy: 0.9579 - val
_loss: 0.1474
Epoch 2/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 5s 3ms/step - accuracy: 0.9611 - loss: 0.1300 - val_accuracy: 0.9659 - val
_loss: 0.1122
Epoch 3/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9739 - loss: 0.0857 - val_accuracy: 0.9669 - val
_loss: 0.1073
Epoch 4/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9819 - loss: 0.0591 - val_accuracy: 0.9702 - val
_loss: 0.0991
Epoch 5/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9849 - loss: 0.0476 - val_accuracy: 0.9732 - val
_loss: 0.0893
Epoch 6/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9892 - loss: 0.0340 - val_accuracy: 0.9730 - val
_loss: 0.0937
Epoch 7/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9907 - loss: 0.0279 - val_accuracy: 0.9738 - val
_loss: 0.0957
Epoch 8/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9930 - loss: 0.0224 - val_accuracy: 0.9738 - val
_loss: 0.1089
Epoch 9/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9944 - loss: 0.0175 - val_accuracy: 0.9741 - val
_loss: 0.1040
Epoch 10/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9953 - loss: 0.0147 - val_accuracy: 0.9715 - val
_loss: 0.1225
Epoch 11/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9950 - loss: 0.0150 - val_accuracy: 0.9688 - val
_loss: 0.1344
Epoch 12/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9953 - loss: 0.0137 - val_accuracy: 0.9758 - val
_loss: 0.1188
Epoch 13/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9961 - loss: 0.0120 - val_accuracy: 0.9727 - val
_loss: 0.1322
Epoch 14/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9962 - loss: 0.0109 - val_accuracy: 0.9755 - val
_loss: 0.1217
Epoch 15/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9971 - loss: 0.0093 - val_accuracy: 0.9740 - val
_loss: 0.1325
Epoch 16/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9966 - loss: 0.0110 - val_accuracy: 0.9747 - val
_loss: 0.1355
Epoch 17/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9968 - loss: 0.0096 - val_accuracy: 0.9765 - val
_loss: 0.1279
Epoch 18/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9974 - loss: 0.0083 - val_accuracy: 0.9708 - val
_loss: 0.1637
Epoch 19/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9964 - loss: 0.0106 - val_accuracy: 0.9747 - val
_loss: 0.1408
Epoch 20/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9977 - loss: 0.0079 - val_accuracy: 0.9751 - val
_loss: 0.1351
Epoch 21/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9974 - loss: 0.0069 - val_accuracy: 0.9774 - val
_loss: 0.1403
Epoch 22/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9982 - loss: 0.0064 - val_accuracy: 0.9746 - val
_loss: 0.1545
Epoch 23/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9975 - loss: 0.0070 - val_accuracy: 0.9775 - val
_loss: 0.1436
Epoch 24/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9977 - loss: 0.0064 - val_accuracy: 0.9765 - val
_loss: 0.1549
Epoch 25/25
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9983 - loss: 0.0049 - val_accuracy: 0.9747 - val
_loss: 0.1769
```

In [20]:
```
y_prob=model.predict(X_test)
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 1s 2ms/step
```

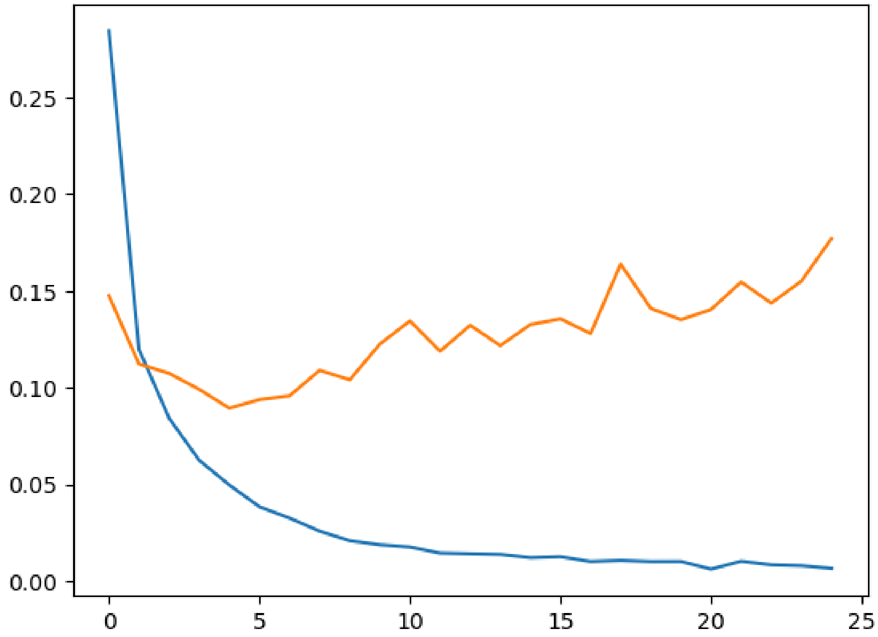
In [21]:
```
y_pred=y_prob.argmax(axis=1)
```

In [22]:
```
from sklearn.metrics import accuracy_score
accuracy_score(y_test,y_pred)
```

Out[22]:
```
0.9755
```

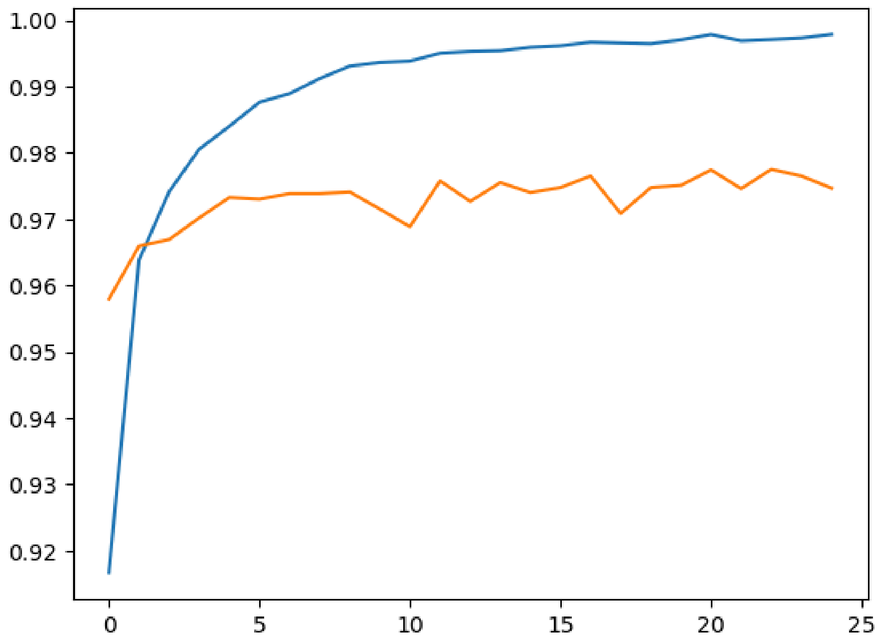
In [26]:
```
plt.plot(history.history['loss'])       #blue
plt.plot(history.history['val_loss'])   #orange
```

Out[26]:
```
[<matplotlib.lines.Line2D at 0x180cb8007d0>]
```



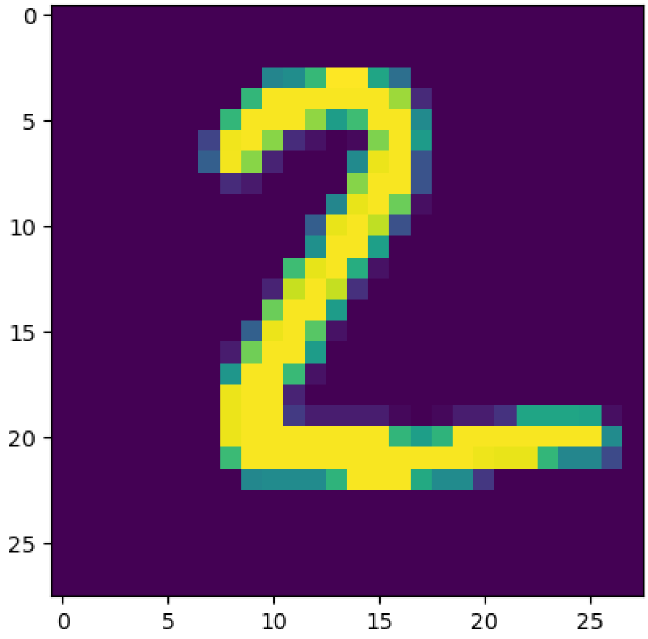
In [27]:
```
plt.plot(history.history['accuracy'])       #blue
plt.plot(history.history['val_accuracy'])   #orange
```

Out[27]:
```
[<matplotlib.lines.Line2D at 0x180cb877cd0>]
```



In [28]:
```
plt.imshow(X_test[1])
```

Out[28]:
```
<matplotlib.image.AxesImage at 0x180cb8f7a50>
```



In [29]:
```
model.predict(X_test[1].reshape(1,28,28)).argmax(axis=1)
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 31ms/step
```

Out[29]:
```
array([2], dtype=int64)
```

Fashion MNIST Dataset

In [1]:
```
import tensorflow
from tensorflow import keras
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Dense,Flatten
```

In [8]:
```
(X_train, y_train), (X_test, y_test) = keras.datasets.fashion_mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-labels-idx1-ubyt
e.gz
29515/29515 ━━━━━━━━━━━━━━━━━━━━ 0s 2us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-images-idx3-ubyt
e.gz
26421880/26421880 ━━━━━━━━━━━━━━━━━━━━ 11s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-labels-idx1-ubyte.
gz
5148/5148 ━━━━━━━━━━━━━━━━━━━━ 0s 1us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-images-idx3-ubyte.
gz
4422102/4422102 ━━━━━━━━━━━━━━━━━━━━ 1s 0us/step
```

In [9]:
```
X_test.shape
```

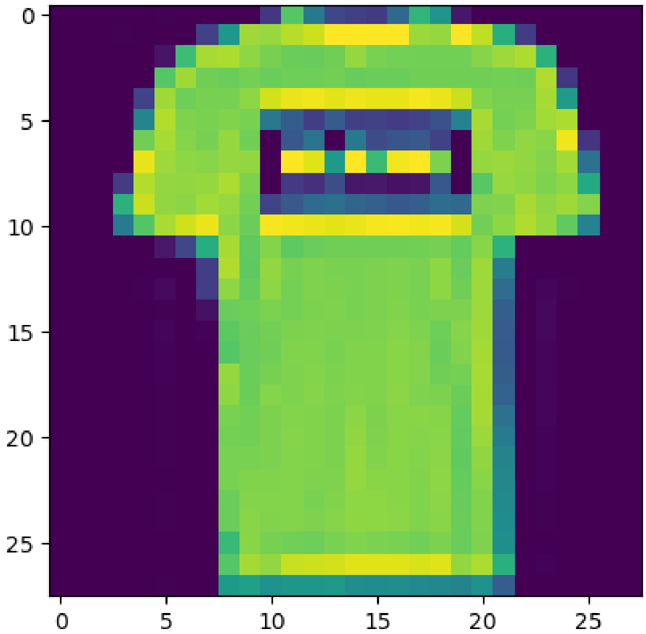
Out[9]:
```
(10000, 28, 28)
```

In [10]:
```
y_train
```

Out[10]:
```
array([9, 0, 0, ..., 3, 0, 5], dtype=uint8)
```

In [50]:
```
import matplotlib.pyplot as plt
plt.imshow(X_train[1])
```

Out[50]:
```
<matplotlib.image.AxesImage at 0x20c277a3d90>
```




```
In [18]: X_train=X_train/255
         X_test=X_test/255
```

```
In [19]: X_train[0]
```

```
Out[19]: 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.        , 0.00392157, 0.        , 0.        ,
          0.05098039, 0.28627451, 0.        , 0.        , 0.00392157,
          0.01568627, 0.        , 0.        , 0.        , 0.        ,
          0.00392157, 0.00392157, 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.01176471, 0.        , 0.14117647,
          0.53333333, 0.49803922, 0.24313725, 0.21176471, 0.        ,
          0.        , 0.        , 0.00392157, 0.01176471, 0.01568627,
          0.        , 0.        , 0.01176471],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.02352941, 0.        , 0.4       ,
          0.8       , 0.69019608, 0.5254902 , 0.56470588, 0.48235294,
          0.09019608, 0.        , 0.        , 0.        , 0.        ,
          0.04705882, 0.03921569, 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.60784314,
          0.9254902 , 0.81176471, 0.69803922, 0.41960784, 0.61176471,
          0.63137255, 0.42745098, 0.25098039, 0.09019608, 0.30196078,
          0.50980392, 0.28235294, 0.05882353],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.00392157, 0.        , 0.27058824, 0.81176471,
          0.8745098 , 0.85490196, 0.84705882, 0.84705882, 0.63921569,
          0.49803922, 0.4745098 , 0.47843137, 0.57254902, 0.55294118,
          0.34509804, 0.6745098 , 0.25882353],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.00392157,
          0.00392157, 0.00392157, 0.        , 0.78431373, 0.90980392,
          0.90980392, 0.91372549, 0.89803922, 0.8745098 , 0.8745098 ,
          0.84313725, 0.83529412, 0.64313725, 0.49803922, 0.48235294,
          0.76862745, 0.89803922, 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.71764706, 0.88235294,
          0.84705882, 0.8745098 , 0.89411765, 0.92156863, 0.89019608,
          0.87843137, 0.87058824, 0.87843137, 0.86666667, 0.8745098 ,
          0.96078431, 0.67843137, 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.75686275, 0.89411765,
          0.85490196, 0.83529412, 0.77647059, 0.70588235, 0.83137255,
          0.82352941, 0.82745098, 0.83529412, 0.8745098 , 0.8627451 ,
          0.95294118, 0.79215686, 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.00392157,
          0.01176471, 0.        , 0.04705882, 0.85882353, 0.8627451 ,
          0.83137255, 0.85490196, 0.75294118, 0.6627451 , 0.89019608,
          0.81568627, 0.85490196, 0.87843137, 0.83137255, 0.88627451,
          0.77254902, 0.81960784, 0.20392157],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.02352941, 0.        , 0.38823529, 0.95686275, 0.87058824,
```

```
        0.8627451 , 0.85490196, 0.79607843, 0.77647059, 0.86666667,
        0.84313725, 0.83529412, 0.87058824, 0.8627451 , 0.96078431,
        0.46666667, 0.65490196, 0.21960784],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.01568627,
        0.        , 0.        , 0.21568627, 0.9254902 , 0.89411765,
        0.90196078, 0.89411765, 0.94117647, 0.90980392, 0.83529412,
        0.85490196, 0.8745098 , 0.91764706, 0.85098039, 0.85098039,
        0.81960784, 0.36078431, 0.        ],
       [0.        , 0.        , 0.00392157, 0.01568627, 0.02352941,
        0.02745098, 0.00784314, 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.92941176, 0.88627451, 0.85098039,
        0.8745098 , 0.87058824, 0.85882353, 0.87058824, 0.86666667,
        0.84705882, 0.8745098 , 0.89803922, 0.84313725, 0.85490196,
        1.        , 0.30196078, 0.        ],
       [0.        , 0.01176471, 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.24313725,
        0.56862745, 0.8       , 0.89411765, 0.81176471, 0.83529412,
        0.86666667, 0.85490196, 0.81568627, 0.82745098, 0.85490196,
        0.87843137, 0.8745098 , 0.85882353, 0.84313725, 0.87843137,
        0.95686275, 0.62352941, 0.        ],
       [0.        , 0.        , 0.        , 0.        , 0.07058824,
        0.17254902, 0.32156863, 0.41960784, 0.74117647, 0.89411765,
        0.8627451 , 0.87058824, 0.85098039, 0.88627451, 0.78431373,
        0.80392157, 0.82745098, 0.90196078, 0.87843137, 0.91764706,
        0.69019608, 0.7372549 , 0.98039216, 0.97254902, 0.91372549,
        0.93333333, 0.84313725, 0.        ],
       [0.        , 0.22352941, 0.73333333, 0.81568627, 0.87843137,
        0.86666667, 0.87843137, 0.81568627, 0.8       , 0.83921569,
        0.81568627, 0.81960784, 0.78431373, 0.62352941, 0.96078431,
        0.75686275, 0.80784314, 0.8745098 , 1.        , 1.        ,
        0.86666667, 0.91764706, 0.86666667, 0.82745098, 0.8627451 ,
        0.90980392, 0.96470588, 0.        ],
       [0.01176471, 0.79215686, 0.89411765, 0.87843137, 0.86666667,
        0.82745098, 0.82745098, 0.83921569, 0.80392157, 0.80392157,
        0.80392157, 0.8627451 , 0.94117647, 0.31372549, 0.58823529,
        1.        , 0.89803922, 0.86666667, 0.7372549 , 0.60392157,
        0.74901961, 0.82352941, 0.8       , 0.81960784, 0.87058824,
        0.89411765, 0.88235294, 0.        ],
       [0.38431373, 0.91372549, 0.77647059, 0.82352941, 0.87058824,
        0.89803922, 0.89803922, 0.91764706, 0.97647059, 0.8627451 ,
        0.76078431, 0.84313725, 0.85098039, 0.94509804, 0.25490196,
        0.28627451, 0.41568627, 0.45882353, 0.65882353, 0.85882353,
        0.86666667, 0.84313725, 0.85098039, 0.8745098 , 0.8745098 ,
        0.87843137, 0.89803922, 0.11372549],
       [0.29411765, 0.8       , 0.83137255, 0.8       , 0.75686275,
        0.80392157, 0.82745098, 0.88235294, 0.84705882, 0.7254902 ,
        0.77254902, 0.80784314, 0.77647059, 0.83529412, 0.94117647,
        0.76470588, 0.89019608, 0.96078431, 0.9372549 , 0.8745098 ,
        0.85490196, 0.83137255, 0.81960784, 0.87058824, 0.8627451 ,
        0.86666667, 0.90196078, 0.2627451 ],
       [0.18823529, 0.79607843, 0.71764706, 0.76078431, 0.83529412,
        0.77254902, 0.7254902 , 0.74509804, 0.76078431, 0.75294118,
        0.79215686, 0.83921569, 0.85882353, 0.86666667, 0.8627451 ,
        0.9254902 , 0.88235294, 0.84705882, 0.78039216, 0.80784314,
        0.72941176, 0.70980392, 0.69411765, 0.6745098 , 0.70980392,
        0.80392157, 0.80784314, 0.45098039],
       [0.        , 0.47843137, 0.85882353, 0.75686275, 0.70196078,
        0.67058824, 0.71764706, 0.76862745, 0.8       , 0.82352941,
        0.83529412, 0.81176471, 0.82745098, 0.82352941, 0.78431373,
        0.76862745, 0.76078431, 0.74901961, 0.76470588, 0.74901961,
        0.77647059, 0.75294118, 0.69019608, 0.61176471, 0.65490196,
        0.69411765, 0.82352941, 0.36078431],
       [0.        , 0.        , 0.29019608, 0.74117647, 0.83137255,
        0.74901961, 0.68627451, 0.6745098 , 0.68627451, 0.70980392,
        0.7254902 , 0.7372549 , 0.74117647, 0.7372549 , 0.75686275,
        0.77647059, 0.8       , 0.81960784, 0.82352941, 0.82352941,
        0.82745098, 0.7372549 , 0.7372549 , 0.76078431, 0.75294118,
        0.84705882, 0.66666667, 0.        ],
       [0.00784314, 0.        , 0.        , 0.        , 0.25882353,
        0.78431373, 0.87058824, 0.92941176, 0.9372549 , 0.94901961,
        0.96470588, 0.95294118, 0.95686275, 0.86666667, 0.8627451 ,
        0.75686275, 0.74901961, 0.70196078, 0.71372549, 0.71372549,
        0.70980392, 0.69019608, 0.65098039, 0.65882353, 0.38823529,
        0.22745098, 0.        , 0.        ],
```

```
 [0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.15686275, 0.23921569, 0.17254902,
  0.28235294, 0.16078431, 0.1372549 , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        ],
 [0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        ],
 [0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        , 0.        , 0.        ,
  0.        , 0.        , 0.        ]])
```

In [22]:

```
model=Sequential()
model.add(Flatten(input_shape=(28,28)))
model.add(Dense(128,activation='relu'))
model.add(Dense(32,activation='relu'))
model.add(Dense(10,activation='softmax'))
```

In [23]:

```
model.summary()
```

Model: "sequential_2"

Layer (type)	Output Shape	Param #
flatten_2 (Flatten)	(None, 784)	0
dense_3 (Dense)	(None, 128)	100,480
dense_4 (Dense)	(None, 32)	4,128
dense_5 (Dense)	(None, 10)	330

Total params: 104,938 (409.91 KB)

Trainable params: 104,938 (409.91 KB)

Non-trainable params: 0 (0.00 B)

In [24]:

```
model.compile(loss='sparse_categorical_crossentropy',optimizer='Adam',metrics=['accuracy'])
```

In [33]:

```
history=model.fit(X_train,y_train,epochs=20,validation_split=0.2)
```

```
Epoch 1/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9507 - loss: 0.1505 - val_accuracy: 0.8825 - val
_loss: 0.4757
Epoch 2/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9559 - loss: 0.1313 - val_accuracy: 0.8917 - val
_loss: 0.4503
Epoch 3/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9582 - loss: 0.1182 - val_accuracy: 0.8867 - val
_loss: 0.4997
Epoch 4/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9564 - loss: 0.1215 - val_accuracy: 0.8903 - val
_loss: 0.4882
Epoch 5/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 2ms/step - accuracy: 0.9604 - loss: 0.1111 - val_accuracy: 0.8831 - val
_loss: 0.4623
Epoch 6/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9617 - loss: 0.1064 - val_accuracy: 0.8905 - val
_loss: 0.4774
Epoch 7/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9634 - loss: 0.1023 - val_accuracy: 0.8905 - val
_loss: 0.4680
Epoch 8/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9623 - loss: 0.1033 - val_accuracy: 0.8941 - val
_loss: 0.4869
Epoch 9/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9653 - loss: 0.0937 - val_accuracy: 0.8882 - val
_loss: 0.4798
Epoch 10/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9653 - loss: 0.0973 - val_accuracy: 0.8894 - val
_loss: 0.4749
Epoch 11/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 6s 3ms/step - accuracy: 0.9641 - loss: 0.1010 - val_accuracy: 0.8913 - val
_loss: 0.5142
Epoch 12/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9668 - loss: 0.0904 - val_accuracy: 0.8866 - val
_loss: 0.5290
Epoch 13/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9663 - loss: 0.0923 - val_accuracy: 0.8878 - val
_loss: 0.5081
Epoch 14/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 5s 3ms/step - accuracy: 0.9681 - loss: 0.0871 - val_accuracy: 0.8915 - val
_loss: 0.5422
Epoch 15/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9649 - loss: 0.0952 - val_accuracy: 0.8868 - val
_loss: 0.5530
Epoch 16/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9703 - loss: 0.0846 - val_accuracy: 0.8895 - val
_loss: 0.5401
Epoch 17/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9688 - loss: 0.0848 - val_accuracy: 0.8893 - val
_loss: 0.5489
Epoch 18/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9678 - loss: 0.0863 - val_accuracy: 0.8881 - val
_loss: 0.5838
Epoch 19/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9692 - loss: 0.0828 - val_accuracy: 0.8903 - val
_loss: 0.5725
Epoch 20/20
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 4s 3ms/step - accuracy: 0.9675 - loss: 0.0846 - val_accuracy: 0.8880 - val
_loss: 0.5996
```

In [34]:
```
y_prob=model.predict(X_test)
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step
```

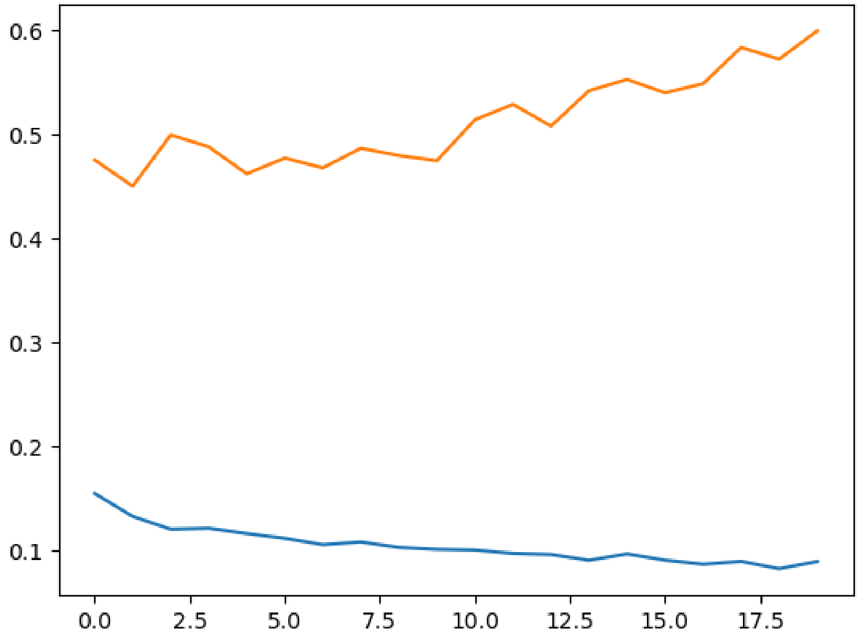
In [35]:
```
y_pred=y_prob.argmax(axis=1)
```

In [36]:
```
from sklearn.metrics import accuracy_score
accuracy_score(y_test,y_pred)
```

Out[36]:
```
0.8817
```

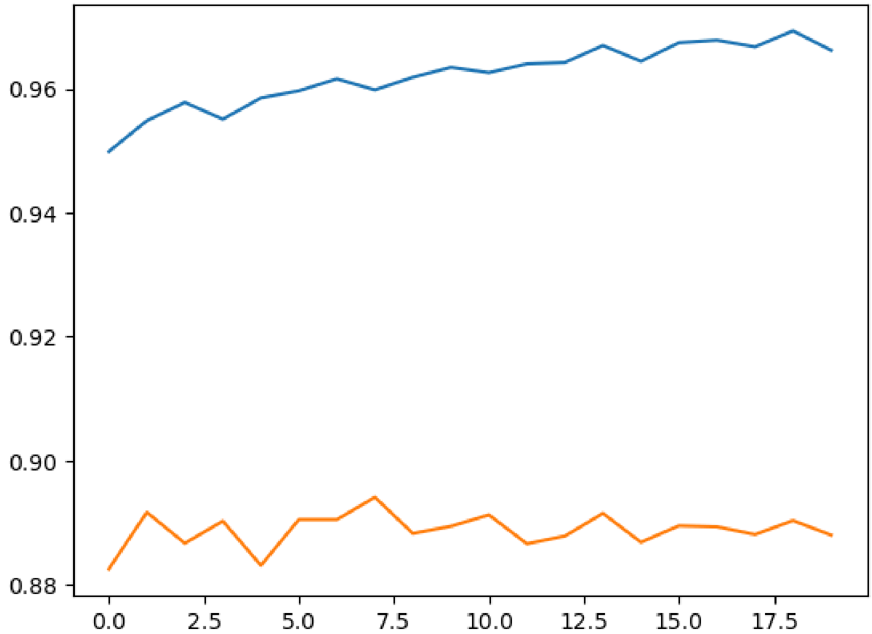
In [37]:
```
plt.plot(history.history['loss'])       #blue
plt.plot(history.history['val_loss'])   #orange
```

Out[37]: [<matplotlib.lines.Line2D at 0x20c0be2cdd0>]



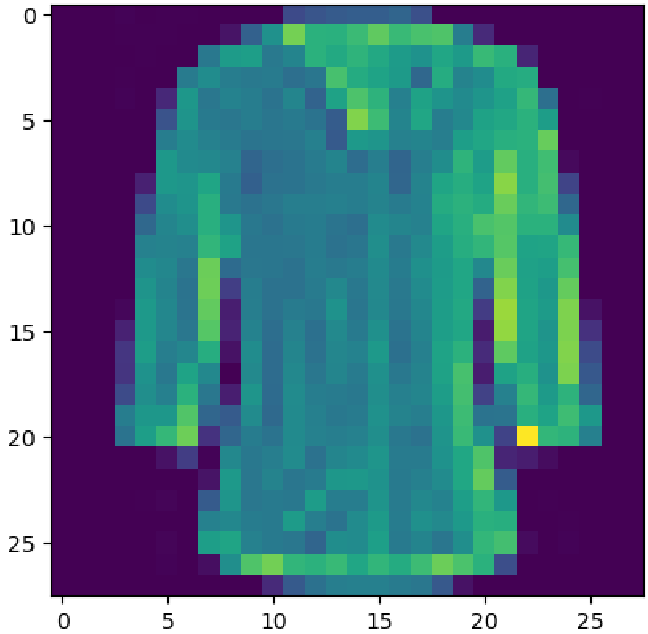
In [38]:
```
plt.plot(history.history['accuracy'])        #blue
plt.plot(history.history['val_accuracy'])    #orange
```

Out[38]: [<matplotlib.lines.Line2D at 0x20c262e73d0>]



In [60]:
```
plt.imshow(X_test[4])
```

Out[60]: <matplotlib.image.AxesImage at 0x20c27b69650>



In [61]:
```
model.predict(X_test[4].reshape(1,28,28)).argmax(axis=1)
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 31ms/step
```

Out[61]:
```
array([6], dtype=int64)
```