```
import numpy as np
import pandas as pd

import tensorflow
from tensorflow import keras
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Dense, Flatten

(X_train,y_train),(X_test,y_test)=keras.datasets.mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
11490434/11490434 [==============================] - 1s 0us/step
```

```
X_train.shape
```

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

```
X_test.shape
```

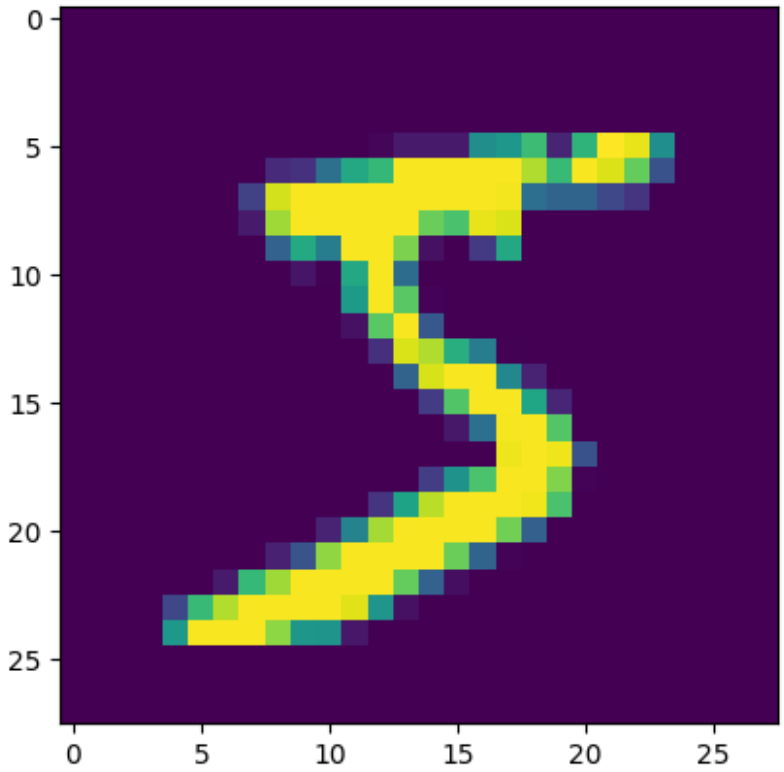
```
(10000, 28, 28)
```

```
y_train
```

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

```
import matplotlib.pyplot as plt
plt.imshow(X_train[0])
```

```
<matplotlib.image.AxesImage at 0x7eecf12177f0>
```




```
X_train[0].shape
```

```
(28, 28)
```

```
X_train = X_train / 255
X_test = X_test / 255
```

```
X_train[0]
```

```
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.        ,
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        0.        , 0.        , 0.        , 0.        , 0.        ,
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        0.        , 0.        , 0.        , 0.        , 0.        ,
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        0.07058824, 0.49411765, 0.53333333, 0.68627451, 0.10196078,
        0.65098039, 1.        , 0.96862745, 0.49803922, 0.        ,
        0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.11764706, 0.14117647,
        0.36862745, 0.60392157, 0.66666667, 0.99215686, 0.99215686,
        0.99215686, 0.99215686, 0.99215686, 0.88235294, 0.6745098 ,
        0.99215686, 0.94901961, 0.76470588, 0.25098039, 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.        , 0.        , 0.07058824, 0.85882353, 0.99215686,
        0.99215686, 0.99215686, 0.99215686, 0.99215686, 0.77647059,
        0.71372549, 0.96862745, 0.94509804, 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
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        0.41960784, 0.99215686, 0.99215686, 0.80392157, 0.04313725,
        0.        , 0.16862745, 0.60392157, 0.        , 0.        ,
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        0.        , 0.        , 0.        ],
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        0.00392157, 0.60392157, 0.99215686, 0.35294118, 0.        ,
        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.        ],
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        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.04313725, 0.74509804, 0.99215686, 0.2745098 ,
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        0.62745098, 0.42352941, 0.00392157, 0.        , 0.        ,
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        0.72941176, 0.99215686, 0.99215686, 0.58823529, 0.10588235,
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        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.0627451 , 0.36470588, 0.98823529, 0.99215686, 0.73333333,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        ],
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        0.00784314, 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
```

```
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        0.99215686, 0.99215686, 0.78823529, 0.30588235, 0.        ,
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        0.        , 0.        , 0.        , 0.09019608, 0.25882353,
        0.83529412, 0.99215686, 0.99215686, 0.99215686, 0.99215686,
        0.77647059, 0.31764706, 0.00784314, 0.        , 0.        ,
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        0.        , 0.        , 0.        ],
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        0.51764706, 0.0627451 , 0.        , 0.        , 0.        ,
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        0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
```

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

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

model.summary()
```

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

 dense (Dense)               (None, 32)                25120

 dense_1 (Dense)             (None, 128)               4224

 dense_2 (Dense)             (None, 10)                1290

=================================================================
Total params: 30634 (119.66 KB)
Trainable params: 30634 (119.66 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

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

history = model.fit(X_train,y_train, epochs=10,validation_split=0.2)
```

```
Epoch 1/10
1500/1500 [==============================] - 7s 3ms/step - loss:
0.3426 - accuracy: 0.8977 - val_loss: 0.1949 - val_accuracy: 0.9440
Epoch 2/10
1500/1500 [==============================] - 7s 5ms/step - loss:
0.1662 - accuracy: 0.9496 - val_loss: 0.1402 - val_accuracy: 0.9578
Epoch 3/10
1500/1500 [==============================] - 9s 6ms/step - loss:
0.1255 - accuracy: 0.9611 - val_loss: 0.1287 - val_accuracy: 0.9609
Epoch 4/10
1500/1500 [==============================] - 7s 5ms/step - loss:
0.1051 - accuracy: 0.9671 - val_loss: 0.1225 - val_accuracy: 0.9620
Epoch 5/10
1500/1500 [==============================] - 5s 3ms/step - loss:
0.0882 - accuracy: 0.9728 - val_loss: 0.1123 - val_accuracy: 0.9641
```

```
Epoch 6/10
1500/1500 [==============================] - 6s 4ms/step - loss:
0.0763 - accuracy: 0.9759 - val_loss: 0.1122 - val_accuracy: 0.9676
Epoch 7/10
1500/1500 [==============================] - 5s 3ms/step - loss:
0.0693 - accuracy: 0.9780 - val_loss: 0.1140 - val_accuracy: 0.9656
Epoch 8/10
1500/1500 [==============================] - 5s 3ms/step - loss:
0.0588 - accuracy: 0.9811 - val_loss: 0.1151 - val_accuracy: 0.9672
Epoch 9/10
1500/1500 [==============================] - 5s 3ms/step - loss:
0.0532 - accuracy: 0.9832 - val_loss: 0.1249 - val_accuracy: 0.9643
Epoch 10/10
1500/1500 [==============================] - 5s 3ms/step - loss:
0.0448 - accuracy: 0.9851 - val_loss: 0.1161 - val_accuracy: 0.9672
```

```
y_prob = model.predict(X_test)
```

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

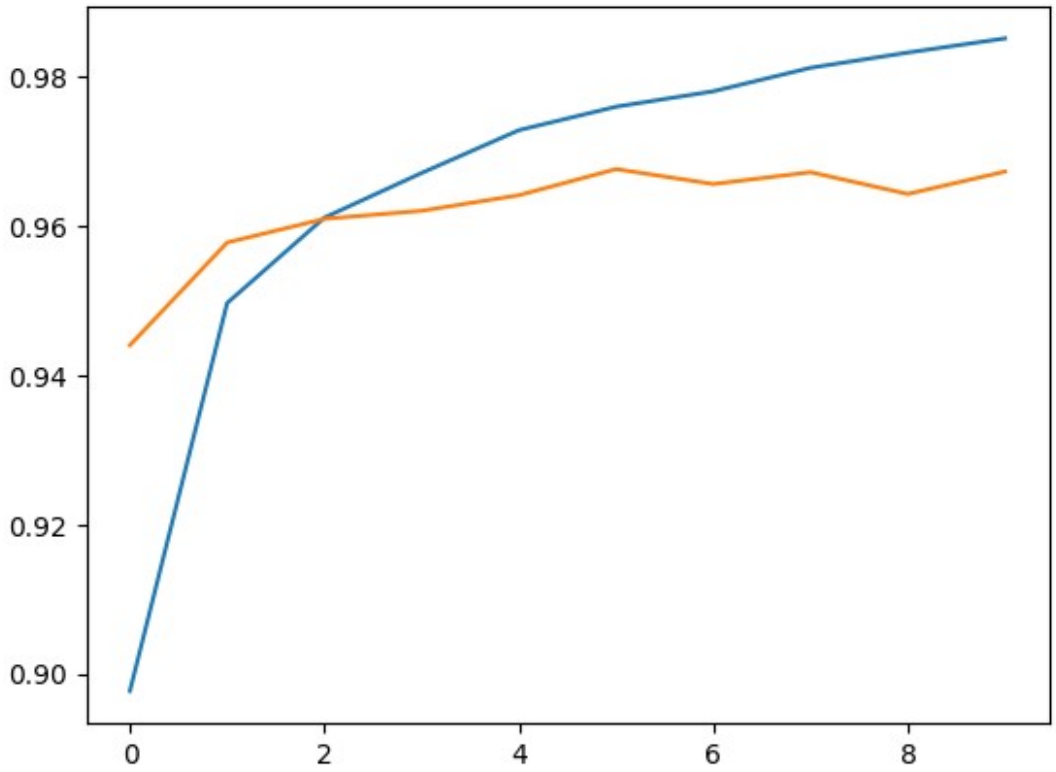
```
y_pred = y_prob.argmax(axis=1)
```

```
from sklearn.metrics import accuracy_score
accuracy_score(y_test,y_pred)
```

```
0.968
```

```
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
```

```
[<matplotlib.lines.Line2D at 0x7eec5065d420>]
```


0.98
0.96
0.94
0.92
0.90
0
2
4
6
8