

# 人工智能实践：TensorFlow 笔记

## 第四讲 功能扩展

### 本讲目标：神经网络八股功能扩展

#### 一、回顾

##### 1、tf.keras 搭建神经网络八股——六步法

- 1) import——导入所需的各种库和包
- 2) x\_train, y\_train——导入数据集、自制数据集、数据增强
- 3) model=tf.keras.models.Sequential  
    /class MyModel(Model) model=MyModel——定义模型
- 4) model.compile——配置模型
- 5) model.fit——训练模型、断点续训
- 6) model.summary——参数提取、acc/loss 可视化、前向推理实现应用

##### 2、代码 mnist\_train\_baseline.py:

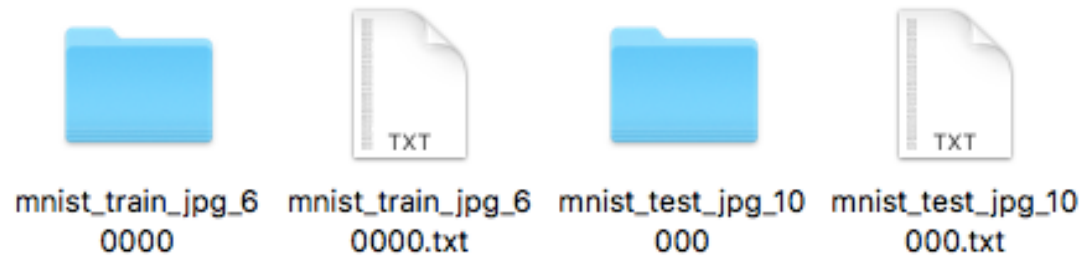
```
1 import tensorflow as tf
2
3 mnist = tf.keras.datasets.mnist
4 (x_train, y_train), (x_test, y_test) = mnist.load_data()
5 x_train, x_test = x_train / 255.0, x_test / 255.0
6
7 model = tf.keras.models.Sequential([
8     tf.keras.layers.Flatten(input_shape=(28, 28)),
9     tf.keras.layers.Dense(128, activation='relu'),
10    tf.keras.layers.Dense(10, activation='softmax')
11 ])
12
13 model.compile(optimizer='adam',
14               loss='sparse_categorical_crossentropy',
15               metrics=['sparse_categorical_accuracy'])
16
17 model.fit(x_train, y_train, batch_size=32, epochs=10, validation_data=(x_test, y_test), validation_freq=1)
18 model.summary()
```

二、本讲用 tf.keras 完善功能模块

1、自制数据集，应对特定应用

1.1、观察数据集数据结构，配成特征标签对

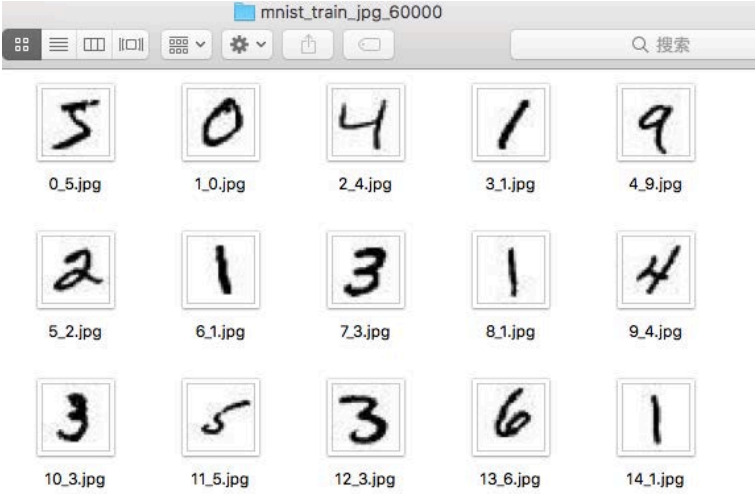
*mnist\_image\_label* 文件夹：



四个文件分别对应为训练集图片、训练集标签、测试集图片、测试集标签

图片文件夹：

黑底白字的灰度图  
28\*28个像素点  
每个像素点都是0-255  
之间的整数（纯黑0，  
纯白255）



标签文件：

```
28755_0.jpg 0
13360_5.jpg 5
57662_5.jpg 5
21455_5.jpg 5
59351_5.jpg 5
39461_3.jpg 3
22720_5.jpg 5
52282_6.jpg 6
10872_3.jpg 3
17077_3.jpg 3
23650_8.jpg 8
56239_0.jpg 0
26079_8.jpg 8
52645_6.jpg 6
12727_2.jpg 2
```

图片名和对应标签，用空格隔开

代码 mnist\_train\_ex1.py:

```
1 import tensorflow as tf
2 from PIL import Image
3 import numpy as np
4
5 train_path = './mnist_image_label/mnist_train_jpg_60000/'
6 train_txt = './mnist_image_label/mnist_train_jpg_60000.txt'
7
8 test_path = './mnist_image_label/mnist_test_jpg_10000/'
9 test_txt = './mnist_image_label/mnist_test_jpg_10000.txt'
10
11 def generateds(path, txt): def generateds(输入特征路径,标签路径文件名)
12     f = open(txt, 'r')
13     contents = f.readlines() # 按行读取
14     f.close()
15     x, y_ = [], []
16     for content in contents:
17         value = content.split() # 以空格分开, 存入数组
18         img_path = path + value[0]
19         img = Image.open(img_path)
20         img = np.array(img.convert('L'))
21         img = img / 255.
22         x.append(img)
23         y_.append(value[1])
24         print('loading : ' + content)
25
26     x = np.array(x)
27     y_ = np.array(y_)
28     y_ = y_.astype(np.int64)
29     return x, y_
30
31 print('-----Generate Data sets-----')
32 x_train, y_train = generateds(train_path, train_txt)
33 x_test, y_test = generateds(test_path, test_txt)
```

读取图片

存入数组

调整格式

返回输入特征和标签

获得训练集和测试集数据

```
35 model = tf.keras.models.Sequential([
36     tf.keras.layers.Flatten(input_shape=(28, 28)),
37     tf.keras.layers.Dense(128, activation='relu'),
38     tf.keras.layers.Dense(10, activation='softmax')
39 ])
40
41 model.compile(optimizer='adam',
42               loss='sparse_categorical_crossentropy',
43               metrics=['sparse_categorical_accuracy'])
44
45 model.fit(x_train, y_train, batch_size=32, epochs=5, validation_data=(x_test, y_test), validation_freq=1)
46 model.summary()
```

2、数据增强，增大数据量

2.1、数据增强（增大数据量）

image\_gen\_train=tf.keras.preprocessing.image.ImageDataGenerator( 增强方法)

image\_gen\_train.fit(x\_train)

常用增强方法:

缩放系数: rescale=所有数据将乘以提供的值 对输入特征的数值大小进行调整

随机旋转: rotation\_range=随机旋转角度数范围 对图像进行角度的随机旋转

宽度偏移: width\_shift\_range=随机宽度偏移量 对图像进行随机宽度偏移

高度偏移: height\_shift\_range=随机高度偏移量

水平翻转: horizontal\_flip=是否水平随机翻转

随机缩放: zoom\_range=随机缩放的范围 [1-n, 1+n] 按什么比例随机缩小/放大图片

```
例: image_gen_train = ImageDataGenerator(  
    rescale=1./255,          #原像素值 0~255 归至 0~1  
    rotation_range=45,       #随机 45 度旋转  
    width_shift_range=.15,   #随机宽度偏移 [-0.15, 0.15)  
    height_shift_range=.15,  #随机高度偏移 [-0.15, 0.15)  
    horizontal_flip=True,    #随机水平翻转  
    zoom_range=0.5           #随机缩放到 [1-50%, 1+50%]
```

代码 mnist\_train\_ex2.py:

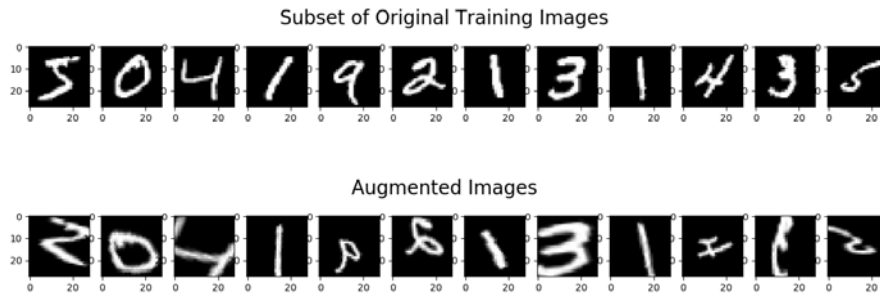
```
1 import tensorflow as tf  
2 from tensorflow.keras.preprocessing.image import ImageDataGenerator  
3  
4 mnist = tf.keras.datasets.mnist  
5 (x_train, y_train), (x_test, y_test) = mnist.load_data()  
6 x_train, x_test = x_train / 255.0, x_test / 255.0  
7  
8 x_train = x_train.reshape(x_train.shape[0], 28, 28, 1) # 给数据增加一个维度, 使数据和网络结构匹配  
9 x_test = x_test.reshape(x_test.shape[0], 28, 28, 1)  
10  
11 image_gen_train = ImageDataGenerator(  
12     rescale=1./255, #如为图像, 分母为255时, 可归至0~1  
13     rotation_range=45, #随机45度旋转  
14     width_shift_range=.15, #宽度偏移  
15     height_shift_range=.15, #高度偏移  
16     horizontal_flip=True, #水平翻转  
17     zoom_range=0.5 #将图像随机缩放范围50%  
18 )  
19 image_gen_train.fit(x_train)  
20  
21 model = tf.keras.models.Sequential([  
22     tf.keras.layers.Flatten(input_shape=(28, 28, 1)),  
23     tf.keras.layers.Dense(128, activation='relu'),  
24     tf.keras.layers.Dense(10, activation='softmax')  
25 ])  
26  
27 model.compile(optimizer='adam',  
28               loss='sparse_categorical_crossentropy',  
29               metrics=['sparse_categorical_accuracy'])  
30  
31 model.fit(image_gen_train.flow(x_train, y_train, batch_size=32), epochs=5, validation_data=(x_test, y_test), validation_freq=1)  
32 model.summary()
```

注: 1、model.fit(x\_train, y\_train, batch\_size=32, ..... ) 变为

model.fit(image\_gen\_train.flow(x\_train, y\_train, batch\_size=32), .....);

2、数据增强函数的输入要求是 4 维, 通过 reshape 调整; 3、如果报错: 缺少  
scipy 库, pip install scipy 即可。

## 2.2、数据增强可视化 (代码 show\_augmented\_images.py)



### 3、断点续训，存取模型

#### 3.1、读取模型

load\_weights(路径文件名)

```
checkpoint_save_path = "./checkpoint/mnist.ckpt"
if os.path.exists(checkpoint_save_path + '.index'):
    print('-----load the model-----')
    model.load_weights(checkpoint_save_path)
```

#### 3.2、保存模型

借助 tensorflow 给出的回调函数，直接保存参数和网络

```
tf.keras.callbacks.ModelCheckpoint(
    filepath=路径文件名,
    save_weights_only=True,
    monitor='val_loss', # val_loss or loss
    save_best_only=True)
```

```
history = model.fit(x_train, y_train, batch_size=32, epochs=5,
                    validation_data=(x_test, y_test), validation_freq=1,
                    callbacks=[cp_callback])
```

注：monitor 配合 save best only 可以保存最优模型，包括：训练损失最小模型、测试损失最小模型、训练准确率最高模型、测试准确率最高模型等。

代码 mnist\_train\_ex3.py:

```

1 import tensorflow as tf
2 import os
3
4 mnist = tf.keras.datasets.mnist
5 (x_train, y_train), (x_test, y_test) = mnist.load_data()
6 x_train, x_test = x_train / 255.0, x_test / 255.0
7
8 model = tf.keras.models.Sequential([
9     tf.keras.layers.Flatten(input_shape=(28, 28)),
10    tf.keras.layers.Dense(128, activation='relu'),
11    tf.keras.layers.Dense(10, activation='softmax')
12 ])
13
14 model.compile(optimizer='adam',
15               loss='sparse_categorical_crossentropy',
16               metrics=['sparse_categorical_accuracy'])
17
18
19 checkpoint_save_path = "./checkpoint/mnist.ckpt"
20 if os.path.exists(checkpoint_save_path + '.index'):
21     print('-----load the model-----')
22     model.load_weights(checkpoint_save_path)
23
24 cp_callback = tf.keras.callbacks.ModelCheckpoint(filepath=checkpoint_save_path,
25                                                  save_weights_only=True,
26                                                  monitor='val_loss', # val_loss or loss
27                                                  save_best_only=True)
28
29 history = model.fit(x_train, y_train, batch_size=32, epochs=5, validation_data=(x_test, y_test), validation_freq=1,
30                    callbacks=[cp_callback])
31 model.summary()

```

#### 4、参数提取，写至文本

##### 4.1、提取可训练参数

model.trainable\_variables 模型中可训练的参数

##### 4.2、设置 print 输出格式

np.set\_printoptions(precision=小数点后按四舍五入保留几位, threshold=数组元素数量少于或等于阈值，打印全部元素；否则打印阈值+1 个元素，中间用省略号补充)

```
>>> np.set_printoptions(precision=5)
```

```
>>> print(np.array([1.123456789]))
```

```
[1.12346]
```

```
>>> np.set_printoptions(threshold=5)
```

```
>>> print(np.arange(10))
```

```
[0 1 2 ... , 7 8 9]
```

注：precision=np.inf 打印完整小数位；threshold=np.nan 打印全部数组元素。

代码 mnist\_train\_ex4.py:

设置显示全部内容

np.inf 表示无穷大

```
1 import tensorflow as tf
2 import os
3 import numpy as np
4
5 np.set_printoptions(threshold=np.inf)
6
7 mnist = tf.keras.datasets.mnist
8 (x_train, y_train), (x_test, y_test) = mnist.load_data()
9 x_train, x_test = x_train / 255.0, x_test / 255.0
10
11 model = tf.keras.models.Sequential([
12     tf.keras.layers.Flatten(input_shape=(28, 28)),
13     tf.keras.layers.Dense(128, activation='relu'),
14     tf.keras.layers.Dense(10, activation='softmax')
15 ])
16
17 model.compile(optimizer='adam',
18               loss='sparse_categorical_crossentropy',
19               metrics=['sparse_categorical_accuracy'])
20
21 checkpoint_save_path = "./checkpoint/mnist.ckpt"
22 if os.path.exists(checkpoint_save_path + '.index'):
23     print('-----load the model-----')
24     model.load_weights(checkpoint_save_path)
25
26 cp_callback = tf.keras.callbacks.ModelCheckpoint(filepath=checkpoint_save_path,
27                                                  save_weights_only=True,
28                                                  monitor='val_loss', # val_loss or loss
29                                                  save_best_only=True)
30
31 history = model.fit(x_train, y_train, batch_size=32, epochs=5, validation_data=(x_test, y_test), validation_freq=1,
32                    callbacks=[cp_callback])
33 model.summary()
34
35 print(model.trainable_variables)
36 file = open('./weights.txt', 'w')
37 for v in model.trainable_variables:
38     file.write(str(v.name) + '\n')
39     file.write(str(v.shape) + '\n')
40     file.write(str(v.numpy()) + '\n')
41 file.close()
```

打印模型参数

存入文本

模型参数打印结果:

```
1.97993845e-01, -2.78407305e-01, -8.17760266e-03,
-7.00537682e-01, -4.84343439e-01, 3.32634568e-01,
3.56431931e-01],
[-4.86615181e-01, 1.56931654e-01, 3.42359006e-01,
4.70145404e-01, -7.82909155e-01, -7.54599690e-01,
-3.46825391e-01, 4.61666703e-01, 1.52707055e-01,
-1.02171159e+00],
[2.49814410e-02, -3.94866347e-01, -2.38858745e-01,
-4.76421565e-01, -8.29285800e-01, 4.69416261e-01,
-2.57994473e-01, 1.95362136e-01, 2.25063980e-01,
1.16042025e-01],
[-1.83508769e-01, 3.88530493e-02, -4.87567544e-01,
-2.24406436e-01, -3.49434733e-01, 4.11300808e-01,
-1.88447893e-01, -2.36360729e-02, -5.55139363e-01,
1.78482935e-01]], dtype=float32)>, <tf.Variable 'dense_1/bias:0' shape=(10,) dtype=float32, numpy=
array([-0.11309464, -0.21033764, -0.02997856, -0.0904652, 0.12025899,
-0.00598264, -0.09277644, -0.22755557, 0.3746695, 0.07525402],
dtype=float32)>]
```

weights.txt:



```

文件(F)  编辑(E)  格式(O)  查看(V)  帮助(H)
dense/kernel:0
(784, 128)
[[-5.28208241e-02  1.77696347e-02  5.36200777e-02 -8.02464187e-02
 -7.40158111e-02  2.43436918e-02  7.37475380e-02 -4.93402593e-02
 -5.28204963e-02 -1.22503266e-02  3.49320099e-02 -6.66563958e-03
  4.27991748e-02  4.25620303e-02  3.26388329e-02 -6.82831556e-03
 -3.72390486e-02  6.31327555e-02  1.49547681e-02 -4.88554873e-02
 -7.91044012e-02  2.88710743e-02  7.29896501e-02 -1.50888264e-02
 -4.08900231e-02 -4.23861295e-02  1.30817220e-02 -3.70090567e-02
  7.55885169e-02  5.81764653e-02 -2.59572975e-02 -4.89420667e-02
 -8.05656984e-02 -2.90985331e-02 -6.55247271e-03 -6.37586638e-02
  1.10701323e-02 -7.90546238e-02 -4.18584831e-02  7.35382959e-02
  8.01183209e-02  8.07191208e-02 -4.53560278e-02 -7.35454261e-04
 -4.34553251e-02 -5.70111275e-02 -3.52828428e-02  1.22970864e-02
 -7.03834444e-02 -2.02142075e-02  4.55207303e-02 -1.19082928e-02
  3.77118587e-04 -1.51321813e-02  7.47007057e-02  5.36825508e-03
 -6.94774091e-02  1.67139769e-02  7.05072358e-02  2.72734016e-02
  2.63411999e-02  7.09173158e-02 -7.11789280e-02 -7.05774128e-03
 -1.76456347e-02  3.48469615e-02 -2.76021659e-03  6.56074658e-02
 -7.71965832e-03  7.47766420e-02 -4.43984345e-02  1.25611573e-03
 -5.33864722e-02 -4.23931293e-02 -7.32599348e-02 -3.05883363e-02
 -7.33513385e-03  6.56326190e-02  4.32138294e-02 -6.28611743e-02
 -2.38207243e-02 -1.37094408e-02  2.65896618e-02  7.17325583e-02]

```

5、acc/loss 可视化，查看效果

### 5.1、acc 曲线与 loss 曲线

history=model.fit(训练集数据, 训练集标签, batch\_size=, epochs=,  
validation\_split=用作测试数据的比例, validation\_data=测试集,  
validation\_freq=测试频率)

*history:*

loss: 训练集 loss

val\_loss: 测试集 loss

sparse\_categorical\_accuracy: 训练集准确率

val\_sparse\_categorical\_accuracy: 测试集准确率

```

acc = history.history['sparse_categorical_accuracy']
val_acc = history.history['val_sparse_categorical_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']

```



history 中读取  
所需数据

画图

画图

```
#####      show      #####

# 显示训练集和验证集的acc和loss曲线
acc = history.history['sparse_categorical_accuracy']
val_acc = history.history['val_sparse_categorical_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']

plt.figure(figsize=(8, 8))
plt.subplot(1, 2, 1)
plt.plot(acc, label='Training Accuracy')
plt.plot(val_acc, label='Validation Accuracy')
plt.title('Training and Validation Accuracy')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(loss, label='Training Loss')
plt.plot(val_loss, label='Validation Loss')
plt.title('Training and Validation Loss')
plt.legend()
plt.show()
```

*acc 和 loss 曲线图:*



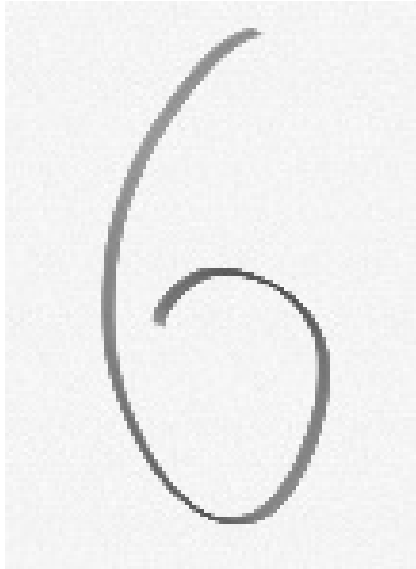
代码 mnist\_train\_ex5.py:

```
1 import tensorflow as tf
2 import os
3 import numpy as np
4 from matplotlib import pyplot as plt
5
6 np.set_printoptions(threshold=np.inf)
7
8 mnist = tf.keras.datasets.mnist
9 (x_train, y_train), (x_test, y_test) = mnist.load_data()
10 x_train, x_test = x_train / 255.0, x_test / 255.0
11
12 model = tf.keras.models.Sequential([
13     tf.keras.layers.Flatten(input_shape=(28, 28)),
14     tf.keras.layers.Dense(128, activation='relu'),
15     tf.keras.layers.Dense(10, activation='softmax')
16 ])
17
18 model.compile(optimizer='adam',
19               loss='sparse_categorical_crossentropy',
20               metrics=['sparse_categorical_accuracy'])
21
22 checkpoint_save_path = "./checkpoint/mnist.ckpt"
23 if os.path.exists(checkpoint_save_path + '.index'):
24     print('-----load the model-----')
25     model.load_weights(checkpoint_save_path)
26
27 cp_callback = tf.keras.callbacks.ModelCheckpoint(filepath=checkpoint_save_path,
28                                                  save_weights_only=True,
29                                                  monitor='val_loss', # val_loss or loss
30                                                  save_best_only=True)
31
32 history = model.fit(x_train, y_train, batch_size=32, epochs=5, validation_data=(x_test, y_test), validation_freq=1,
33                    callbacks=[cp_callback])
34 model.summary()
35
36 print(model.trainable_variables)
37 file = open('./weights.txt', 'w')
38 for v in model.trainable_variables:
39     file.write(str(v.name) + '\n')
40     file.write(str(v.shape) + '\n')
41     file.write(str(v.numpy()) + '\n')
42 file.close()
43
44 ##### show #####
45
46 # 显示训练集和验证集的acc和loss曲线
47 acc = history.history['sparse_categorical_accuracy']
48 val_acc = history.history['val_sparse_categorical_accuracy']
49 loss = history.history['loss']
50 val_loss = history.history['val_loss']
51
52 plt.figure(figsize=(8, 8))
53 plt.subplot(1, 2, 1)
54 plt.plot(acc, label='Training Accuracy')
55 plt.plot(val_acc, label='Validation Accuracy')
56 plt.title('Training and Validation Accuracy')
57 plt.legend()
58
59 plt.subplot(1, 2, 2)
60 plt.plot(loss, label='Training Loss')
61 plt.plot(val_loss, label='Validation Loss')
62 plt.title('Training and Validation Loss')
63 plt.legend()
64 plt.show()
```

## 6、应用程序，给图识物

### 6.1、给图识物

输入一张手写数字图片：



神经网络自动识别出值：



手写十个数，正确率 90%以上合格。

### 6.2、前向传播执行应用

`predict`(输入数据, `batch_size`=整数) 返回前向传播计算结果

注：predict 参数详解。(1)x：输入数据，Numpy 数组（或者 Numpy 数组的列表，如果模型有多个输出）；(2)batch\_size：整数，由于 GPU 的特性，batch\_size 最好选用 8, 16, 32, 64……，如果未指定，默认为 32；(3)verbose：日志显示模式,0 或 1；(4)steps：声明预测结束之前的总步数(批次样本)，默认值 None；(5)返回：预测的 Numpy 数组（或数组列表）。

代码 `mnist_appl.py`：

```

1  from PIL import Image
2  import numpy as np
3  import tensorflow as tf
4  import os
5
6  model_save_path = './checkpoint/mnist.ckpt'
7  model = tf.keras.models.Sequential([
8      tf.keras.layers.Flatten(input_shape=(28, 28)),
9      tf.keras.layers.Dense(128, activation='relu'),
10     tf.keras.layers.Dense(10, activation='softmax')
11 ])
12
13  model.load_weights(model_save_path)
14
15  preNum = int(input("input the number of test pictures:"))
16  for i in range(preNum):
17     image_path = input("the path of test picture:")
18
19     img = Image.open(image_path)
20
21     img=img.resize((28,28),Image.ANTIALIAS)
22     img_arr = np.array(img.convert('L'))
23
24     for i in range(28):
25         for j in range(28):
26             if img_arr[i][j]<200:
27                 img_arr[i][j]=255
28             else:
29                 img_arr[i][j]=0
30
31     img_arr=img_arr/255.0
32
33     x_predict = img_arr[tf.newaxis,...]
34
35     result = model.predict(x_predict)
36     pred=tf.argmax(result, axis=1)
37     print('\n')
38     tf.print(pred)

```

加载模型

预测图片数量

预测图片路径

打开图片

调整尺寸和类型

二值化

预测

输出结果

注:1、输出结果 pred 是张量,需要用 tf.print,print 打印出来是 tf.Tensor([1], shape=(1,), dtype=int64); 2、去掉二值化,出现无法收敛问题,需要对数据集进行归一化。

输出结果:

```

input the number of test pictures:10
the path of test picture:./pic/1.png

[1]
the path of test picture:./pic/2.png

[2]

```

代码 mnist\_app2.py:

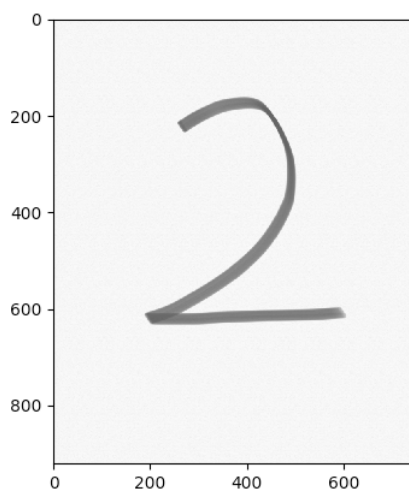
显示图片

```
18 for i in range(preNum):
19     image_path = input("the path of test picture:")
20     img = Image.open(image_path)
21
22     image = plt.imread(image_path)
23     plt.set_cmap('gray')
24     plt.imshow(image)
25
26     img=img.resize((28,28),Image.ANTIALIAS)
27     img_arr = np.array(img.convert('L'))
28
29
30     for i in range(28):
31         for j in range(28):
32             if img_arr[i][j]<200:
33                 img_arr[i][j]=255
34             else:
35                 img_arr[i][j]=0
36
37     img_arr=img_arr/255.0
38     x_predict = img_arr[tf.newaxis,...]
39     result = model.predict(x_predict)
40     pred=tf.argmax(result, axis=1)
41
42     print('\n')
43     tf.print(pred)
44
45     plt.pause(1)
46     plt.close()
```

暂停 1 秒后

关闭图片

可视化图片:

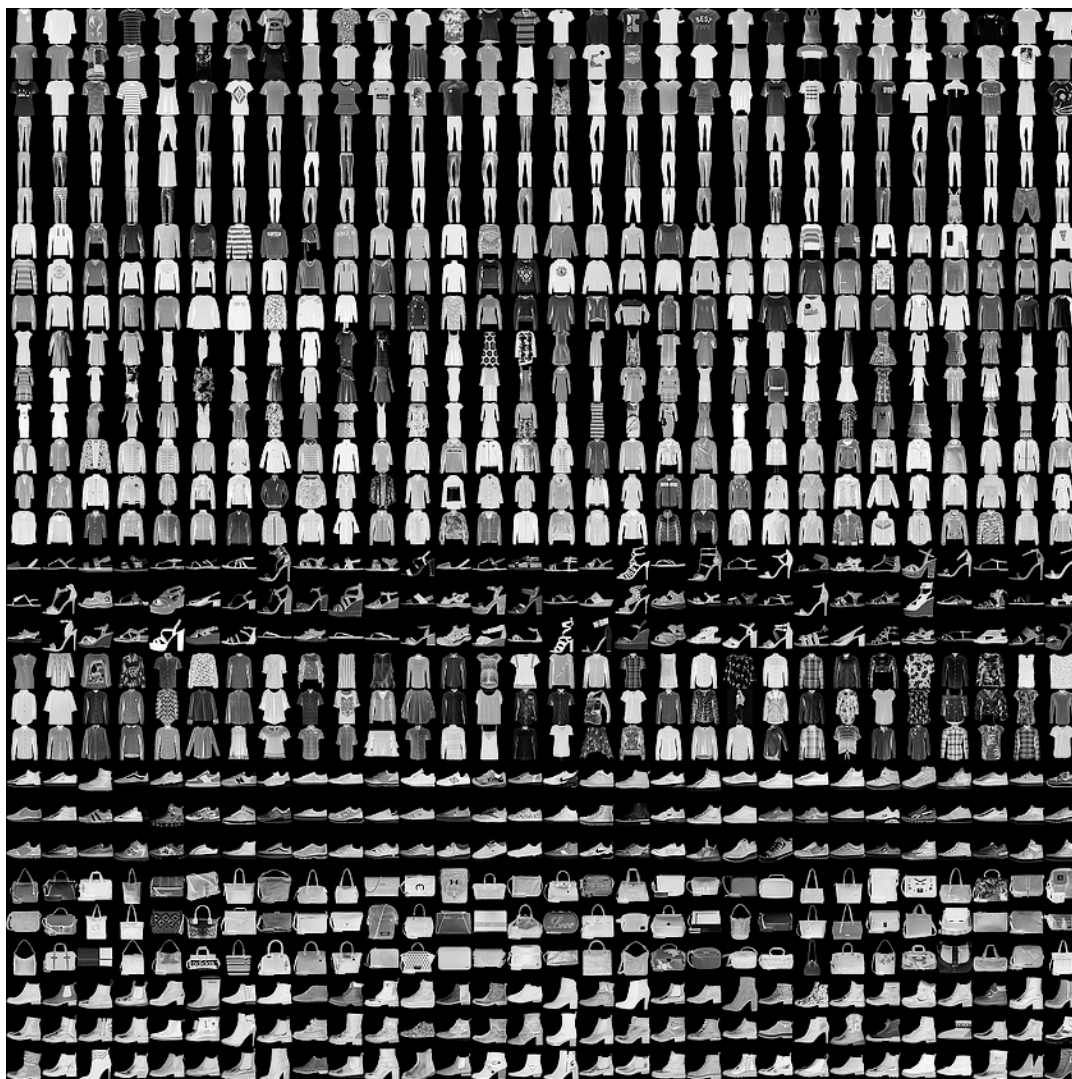


三、补充

1、数据集 Fashion\_mnist

| Label | Description      |
|-------|------------------|
| 0     | T恤 (T-shirt/top) |
| 1     | 裤子 (Trouser)     |
| 2     | 套头衫 (Pullover)   |
| 3     | 连衣裙 (Dress)      |
| 4     | 外套 (Coat)        |
| 5     | 凉鞋 (Sandal)      |
| 6     | 衬衫 (Shirt)       |
| 7     | 运动鞋 (Sneaker)    |
| 8     | 包 (Bag)          |
| 9     | 靴子 (Ankle boot)  |

60000 张训练图像和对应标签；  
10000 张测试图像和对应标签；  
每张图像 28x28 的分辨率。



注：load fashion mnist 数据集 x train.shape: (60000, 28, 28)无通道数；  
送入卷积前先reshape成 x train.shape: (60000, 28, 28, 1)