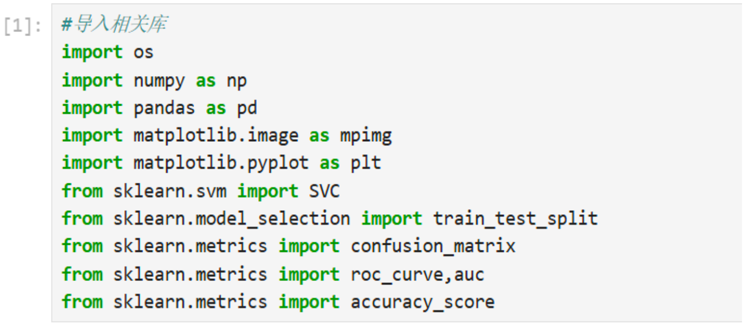
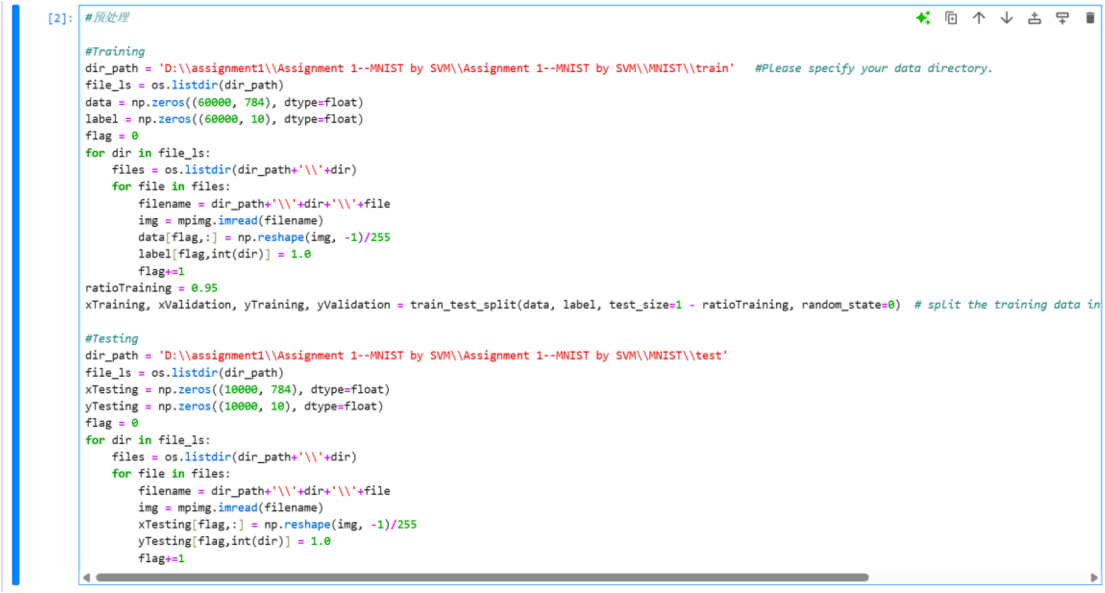
选用 anaconda 版本 Jupyter notebook 作为 python 编辑器，python 解释器为 anaconda 发行版

导入需要的库函数



```
[1]: #导入相关库
     import os
     import numpy as np
     import pandas as pd
     import matplotlib.image as mpimg
     import matplotlib.pyplot as plt
     from sklearn.svm import SVC
     from sklearn.model_selection import train_test_split
     from sklearn.metrics import confusion_matrix
     from sklearn.metrics import roc_curve,auc
     from sklearn.metrics import accuracy_score
```

数据预处理，把图片数据读入训练集和测试集，并将训练集划出 5%为验证集

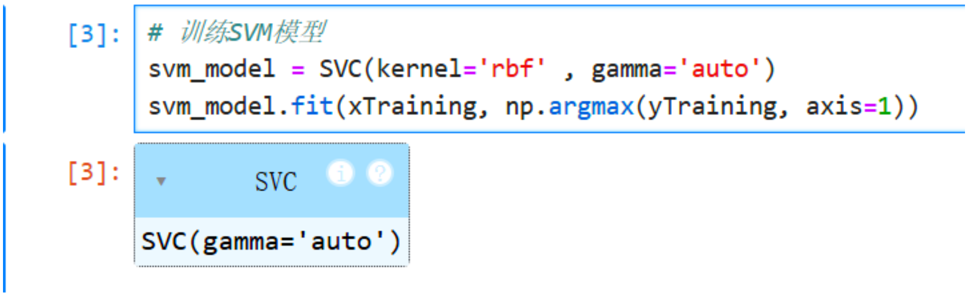


```
[2]: #预处理

     #Training
     dir_path = 'D:\\assignment1\\Assignment 1--MNIST by SVM\\Assignment 1--MNIST by SVM\\MNIST\\train'   #Please specify your data directory.
     file_ls = os.listdir(dir_path)
     data = np.zeros((60000, 784), dtype=float)
     label = np.zeros((60000, 10), dtype=float)
     flag = 0
     for dir in file_ls:
         files = os.listdir(dir_path+'\\'+dir)
         for file in files:
             filename = dir_path+'\\'+dir+'\\'+file
             img = mpimg.imread(filename)
             data[flag,:] = np.reshape(img, -1)/255
             label[flag,int(dir)] = 1.0
             flag+=1
     ratioTraining = 0.95
     xTraining, xValidation, yTraining, yValidation = train_test_split(data, label, test_size=1 - ratioTraining, random_state=0)  # split the training data in

     #Testing
     dir_path = 'D:\\assignment1\\Assignment 1--MNIST by SVM\\Assignment 1--MNIST by SVM\\MNIST\\test'
     file_ls = os.listdir(dir_path)
     xTesting = np.zeros((10000, 784), dtype=float)
     yTesting = np.zeros((10000, 10), dtype=float)
     flag = 0
     for dir in file_ls:
         files = os.listdir(dir_path+'\\'+dir)
         for file in files:
             filename = dir_path+'\\'+dir+'\\'+file
             img = mpimg.imread(filename)
             xTesting[flag,:] = np.reshape(img, -1)/255
             yTesting[flag,int(dir)] = 1.0
             flag+=1
```

选用 RBF 内核，开始训练拟合模型，用时一分钟左右

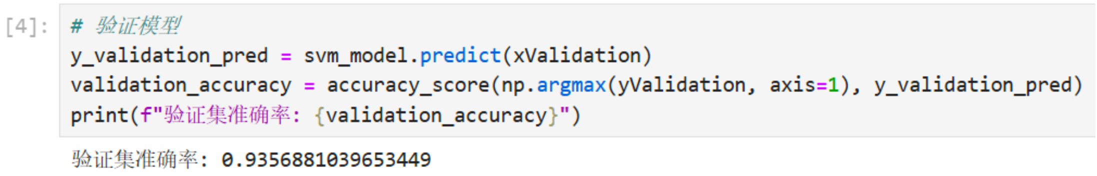


```
[3]: #  训练SVM模型
     svm_model = SVC(kernel='rbf' , gamma='auto')
     svm_model.fit(xTraining, np.argmax(yTraining, axis=1))

[3]:  ▾ SVC

     SVC(gamma='auto')
```

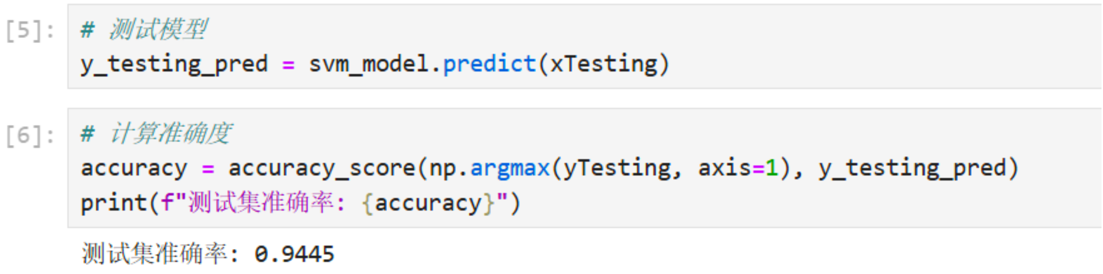
用验证集验证训练好的模型，得准确率为 93.5688%



```
[4]: # 验证模型
     y_validation_pred = svm_model.predict(xValidation)
     validation_accuracy = accuracy_score(np.argmax(yValidation, axis=1), y_validation_pred)
     print(f"验证集准确率: {validation_accuracy}")

     验证集准确率: 0.9356881039653449
```

用测试集正式进行测试，得准确率 94.45%

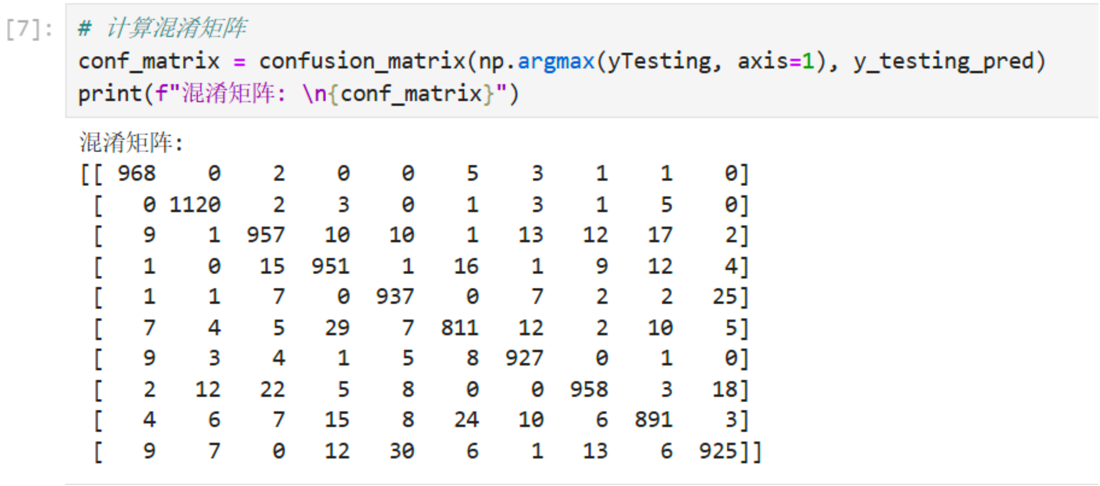


```
[5]: # 测试模型
     y_testing_pred = svm_model.predict(xTesting)

[6]: # 计算准确度
     accuracy = accuracy_score(np.argmax(yTesting, axis=1), y_testing_pred)
     print(f"测试集准确率: {accuracy}")

     测试集准确率: 0.9445
```

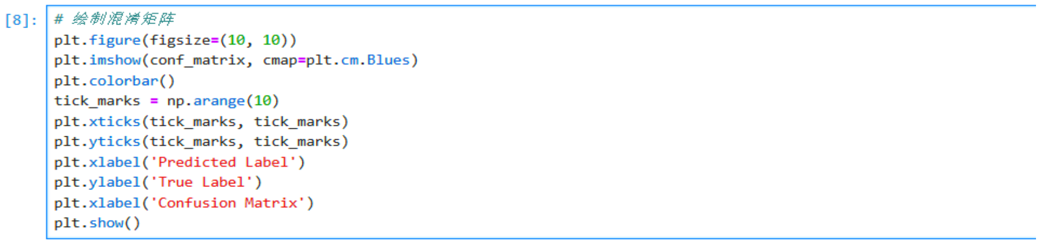
调用 sklearn.metrics 里的 confusion_matrix 方法直接计算得到混淆矩阵



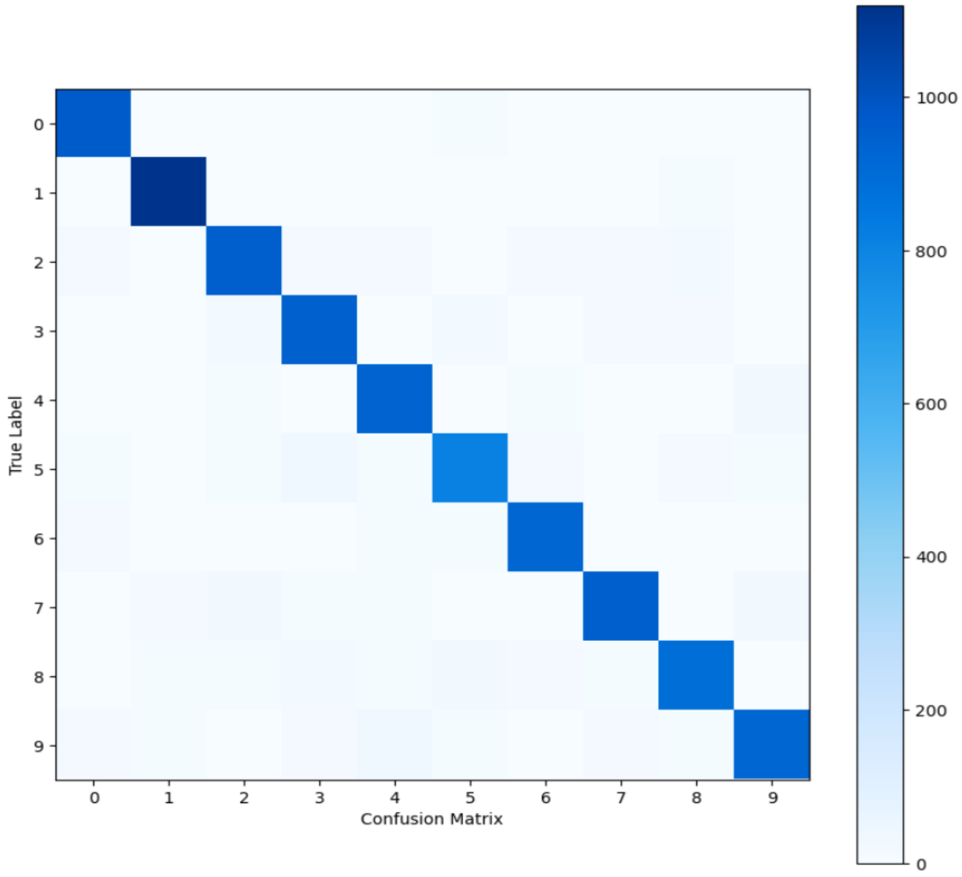
```
[7]: # 计算混淆矩阵
     conf_matrix = confusion_matrix(np.argmax(yTesting, axis=1), y_testing_pred)
     print(f"混淆矩阵: \n{conf_matrix}")

     混淆矩阵:
     [[ 968    0    2    0    0    5    3    1    1    0]
      [   0 1120    2    3    0    1    3    1    5    0]
      [   9    1  957   10   10    1   13   12   17    2]
      [   1    0   15  951    1   16    1    9   12    4]
      [   1    1    7    0  937    0    7    2    2   25]
      [   7    4    5   29    7  811   12    2   10    5]
      [   9    3    4    1    5    8  927    0    1    0]
      [   2   12   22    5    8    0    0  958    3   18]
      [   4    6    7   15    8   24   10    6  891    3]
      [   9    7    0   12   30    6    1   13    6  925]]
```

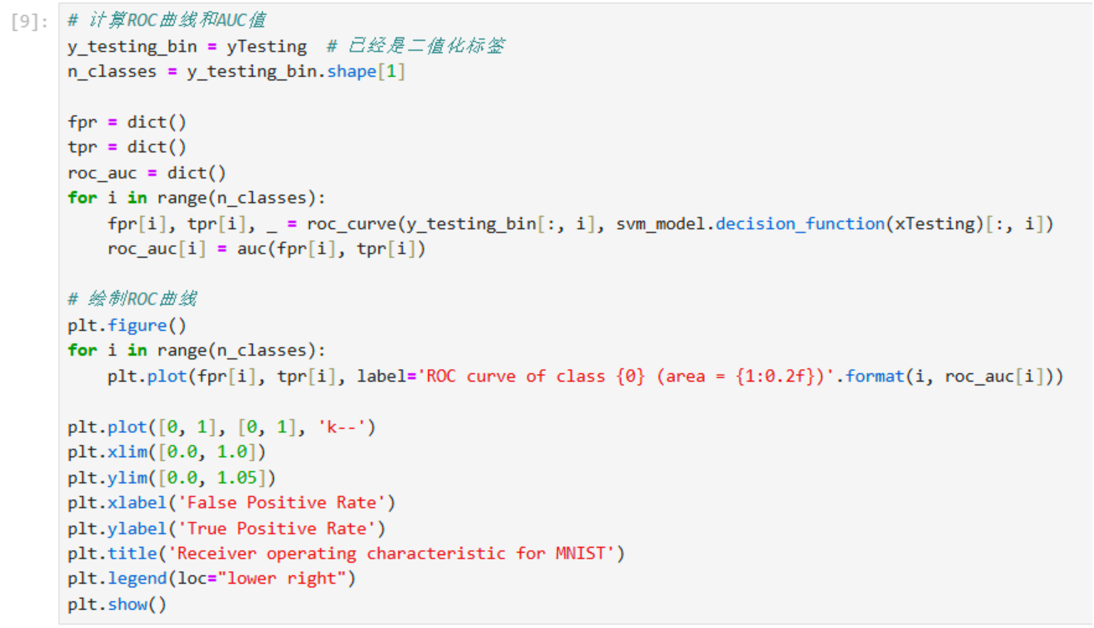
可视化混淆矩阵



```
[8]: # 绘制混淆矩阵
     plt.figure(figsize=(10, 10))
     plt.imshow(conf_matrix, cmap=plt.cm.Blues)
     plt.colorbar()
     tick_marks = np.arange(10)
     plt.xticks(tick_marks, tick_marks)
     plt.yticks(tick_marks, tick_marks)
     plt.xlabel('Predicted Label')
     plt.ylabel('True Label')
     plt.xlabel('Confusion Matrix')
     plt.show()
```



计算和绘制 ROC 曲线（耗时近十分钟）



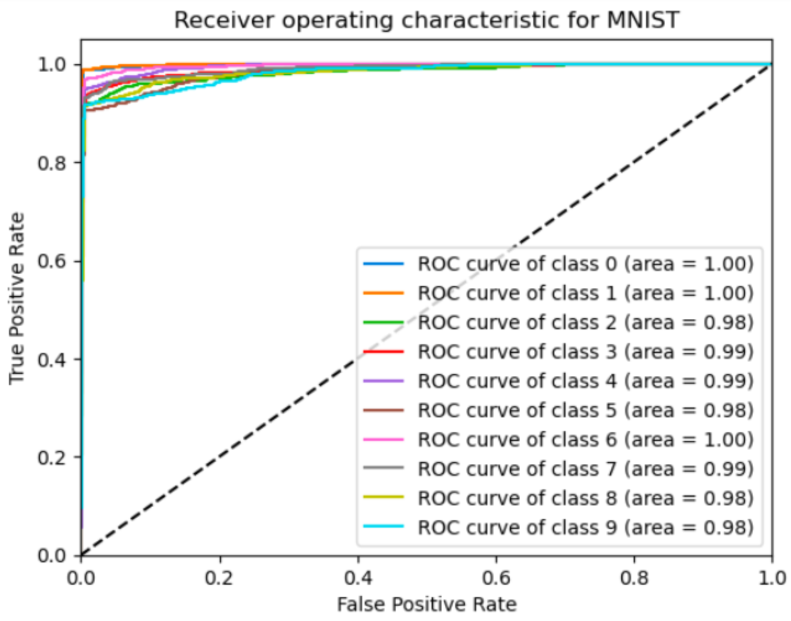
[9]:

```python
# 计算ROC曲线和AUC值
y_testing_bin = yTesting  # 已经是二值化标签
n_classes = y_testing_bin.shape[1]

fpr = dict()
tpr = dict()
roc_auc = dict()
for i in range(n_classes):
    fpr[i], tpr[i], _ = roc_curve(y_testing_bin[:, i], svm_model.decision_function(xTesting)[:, i])
    roc_auc[i] = auc(fpr[i], tpr[i])

# 绘制ROC曲线
plt.figure()
for i in range(n_classes):
    plt.plot(fpr[i], tpr[i], label='ROC curve of class {0} (area = {1:0.2f})'.format(i, roc_auc[i]))

plt.plot([0, 1], [0, 1], 'k--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver operating characteristic for MNIST')
plt.legend(loc="lower right")
plt.show()
```


Receiver operating characteristic for MNIST
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 1.00)
ROC curve of class 1 (area = 1.00)
ROC curve of class 2 (area = 0.98)
ROC curve of class 3 (area = 0.99)
ROC curve of class 4 (area = 0.99)
ROC curve of class 5 (area = 0.98)
ROC curve of class 6 (area = 1.00)
ROC curve of class 7 (area = 0.99)
ROC curve of class 8 (area = 0.98)
ROC curve of class 9 (area = 0.98)