1.5 Machine learning

Definition:
Machine learning is a multidisciplinary interdisciplinary subject, covering the knowledge of probability theory, statistics, approximate theory and complex algorithms.

Machine learning has the following definitions:
(1) Machine learning is a science of artificial intelligence. The main research object in this field is artificial intelligence.
(2) Machine learning is the study of computer algorithms that can be improved automatically through experience.
(3) Machine learning uses data or past experience to optimize the performance standards of computer programs.

1.5.1 KNN (K Nearest Neighbor Algorithm) recognizes handwritten digits

The idea of KNN is, In the feature space, if most of the k nearest feature samples in a sample belong to a certain category, the sample also belongs to this category.

The working principle of KNN, there is a sample data set (training sample set), and each data in the sample set has a label, that is, we know the corresponding relationship between each data in the sample set and the category to which it belongs. After inputting unlabeled data, compare each feature in the new data with the feature corresponding to the data in the sample set, and extract the classification label of the data with the most similar features in the sample set.

In generally, we only select the top K most similar data in the sample data set. This is the source of K in the K nearest neighbor algorithm, K is an integer smaller than 20. Finally, the classification with the most occurrences of the K most similar data is selected as the classification of the new data.

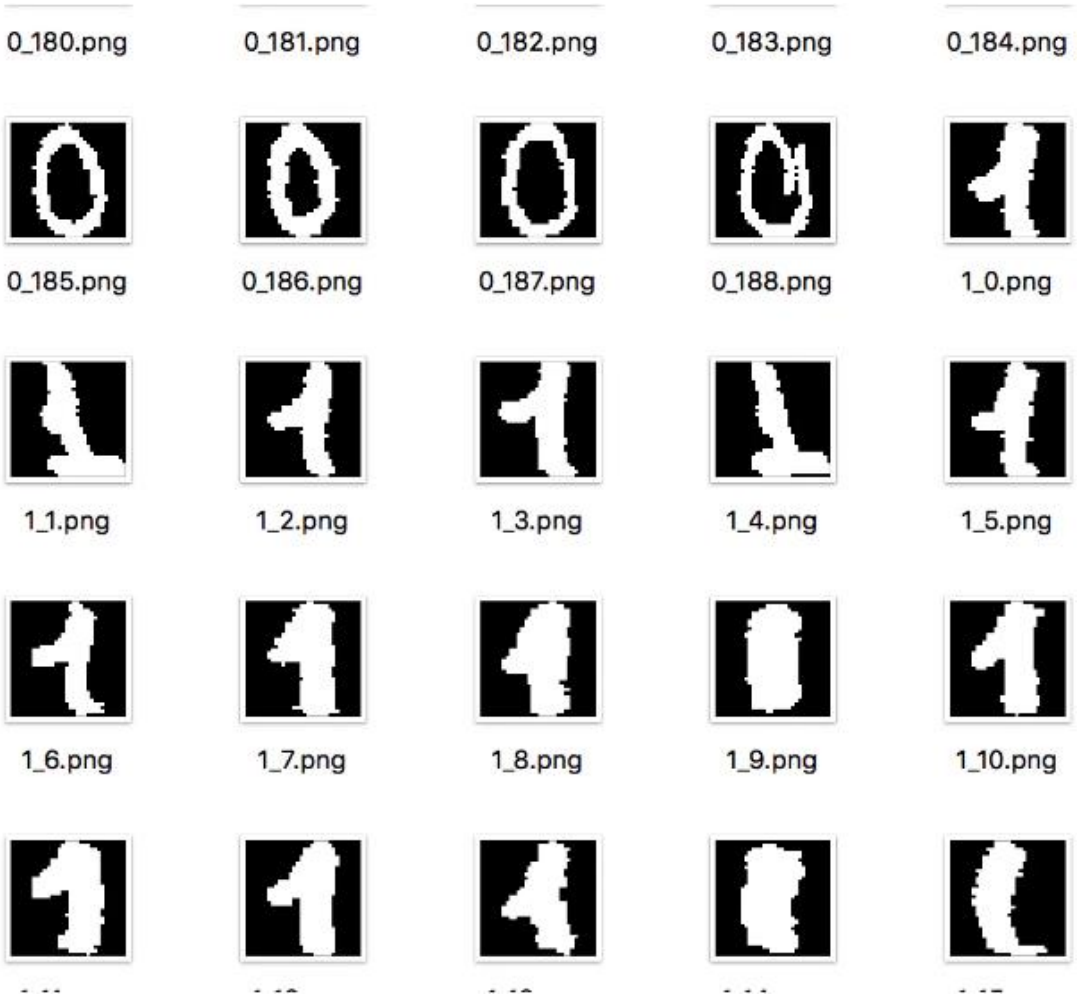
KNN advantages:
1) Flexible usage
2) Convenient for small sample prediction
3) High accuracy
KNN disadvantages:
1) Lack of training stage, unable to cope with multiple samples
2) Calculation more complex and space more complex

KNN implementation steps:
1) Calculate distance
The Euclidean distance formula is shown below,

$$L_2(x_i, x_j) = (\sum_{l=1}^{n} |x_i^{(l)} - x_j^{(l)}|^2)^{\frac{1}{2}}$$

2) Sort according to the increasing relationship of distance;
3) Select K points with the smallest distance (less than 20 points);
4) Determine the frequency of occurrence of the category of the K points;
Frequency of occurrence = category/k
5) Return the category with the highest frequency among the K points as the predicted classification of the test data.

Next, we take the recognition of handwritten digits as an example to briefly introduce the implementation of the KNN algorithm.



【32*32 Pixel data set】

```
00000000000111110000000000000000
00000000001111111000000000000000
00000000011111111100000000000000
00000000111111111110000000000000
00000001111111111111000000000000
00000011111110111111100000000000
00000011111100011111110000000000
00000011111100001111110000000000
00000111111100000111111000000000
00000111111100000011111000000000
00000011111100000001111110000000
00000111111100000000111111000000
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00000011111100000000111111000000
00000001111110000000111111100000
00000000111110000001111111000000
00000000111110000011111110000000
00000000111111000111111100000000
00000000111111111111111000000000
00000000111111111111110000000000
00000000011111111111100000000000
```

【Text data】

The data set is divided into training set and testing set, where the training set is already classified data, and the testing set is used to test the algorithm.

1.Recognize handwritten number to determine K value

Code path:

/home/pi/Yahboom_Project/1.OpenCV_course/05machine_learning/01KNN/KNN_1.ipynb

Convert data to feature vectors

It can be seen from the above figure that we get a 32*32 matrix, each point is a pixel value, and convert these 1024 (32x32) values into a (1,1024) vector.

```
# Convert image data to (1,1024) vector
def img2vector(filename):
    returnVect = numpy.zeros((1, 1024))
    file = open(filename)
    for i in range(32):
        lineStr = file.readline()
        for j in range(32):
            returnVect[0, 32 * i + j] = int(lineStr[j])
    return returnVect
```

KNN Classifier

```
# kNN Classifier
def classifier(inX, dataSet, labels, k):
    # numpy shape [0] return the number of rows in the array, shape [1] returns the
number of columns
    #MDS
    dataSetSize = dataSet.shape[0]
    # The inverse matrix
    diffMat = numpy.tile(inX, (dataSetSize, 1)) - dataSet
    # subtract a 2-d feature and you multiply it
    sqDiffMat = diffMat ** 2
    # Calculation of distance
    sqDistances = sqDiffMat.sum(axis=1)
    distances = sqDistances ** 0.5
    print ("distances:",distances)
    #Returns the index of the elements in distance sorted from smallest to largest
    sortedDistIndicies = distances.argsort()
    print ("sortDistance:",sortDistance)
    classCount = {}
    for i in range(k):
        #Take the categories of the first k elements
        voteIlabel = labels[sortedDistIndicies[i]]
        classCount[voteIlabel] = classCount.get(voteIlabel, 0) + 1
    #reverse
    sortedClassCount = sorted(classCount.items(), key=operator.itemgetter(1),
reverse=True)
    return sortedClassCount[0][0]
```

Input test set, test algorithm

```
# Test the handwritten number recognition code
def handWritingClassTest(k):
    hwLabels = []
    trainingFileList = os.listdir('knn-digits/trainingDigits')
    m = len(trainingFileList)
    trainingMat = numpy.zeros((m, 1024))
```

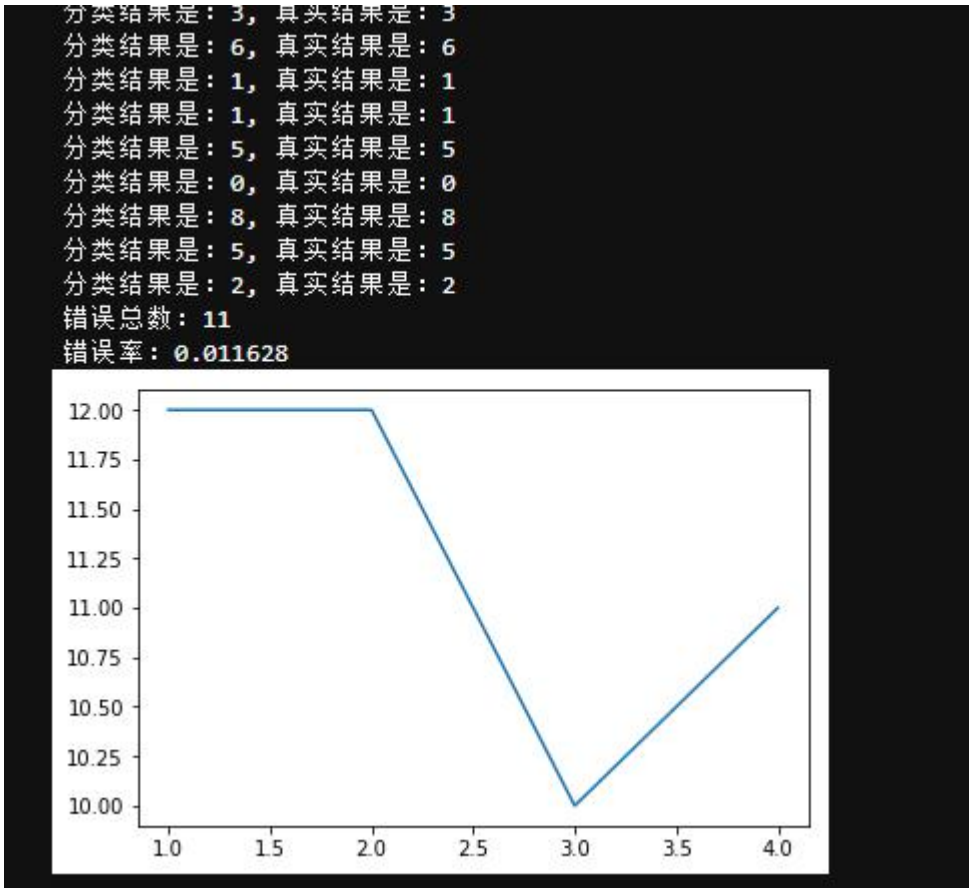
```
    for i in range(m):
        fileNameStr = trainingFileList[i]
        fileStr = fileNameStr.split('.')[0]
        try:
            classNumStr = int(fileStr.split('_')[0])
        except Exception as e:
            print('Error:', e)

        hwLabels.append(classNumStr)
        trainingMat[i, :] = img2vector("knn-digits/trainingDigits/%s" % fileNameStr)

    testFileList = os.listdir('knn-digits/testDigits')
    errorCount = 0.0
    mTest = len(testFileList)
    for i in range(mTest):
        fileNameStr = testFileList[i]
        fileStr = fileNameStr.split('.')[0]
        classNumStr = int(fileStr.split('_')[0])
        vectorTest = img2vector("knn-digits/testDigits/%s" % fileNameStr)
        result = classifier(vectorTest, trainingMat, hwLabels, k)
        print("The classification result is:%d, The real result is:%d" % (result,
classNumStr))
        if result != classNumStr:
            errorCount += 1.0
    print("Total number of errors:%d" % errorCount)
    print("Error rate:%f" % (errorCount/mTest))
    return errorCount
```

Choose a different k value to view the classification effect

```
# Choose a different k value to view the classification effect
def selectK():
    x = list()
    y = list()
    for i in range(1, 5):
        x.append(int(i))
        y.append(int(handWritingClassTest(i)))
    plt.plot(x, y)
    # Due to the relatively long execution time of the program, here is a voice
reminder when the program execution is completed (for Mac, Windows users
remove this line of code)
    os.system("say 'The program is finished'")
    plt.show()
```

```
# Start the test, a line chart will be generated
selectK()
```

After running the program, we can see the results shown in the figure below.



The experimental results prove that taking k = 3 with a better effect. You can also try other values, but the speed is very slow.

The following is tested with k = 3:

```
handWritingClassTest(3)
```

After running the program, we can see the results shown in the figure below.

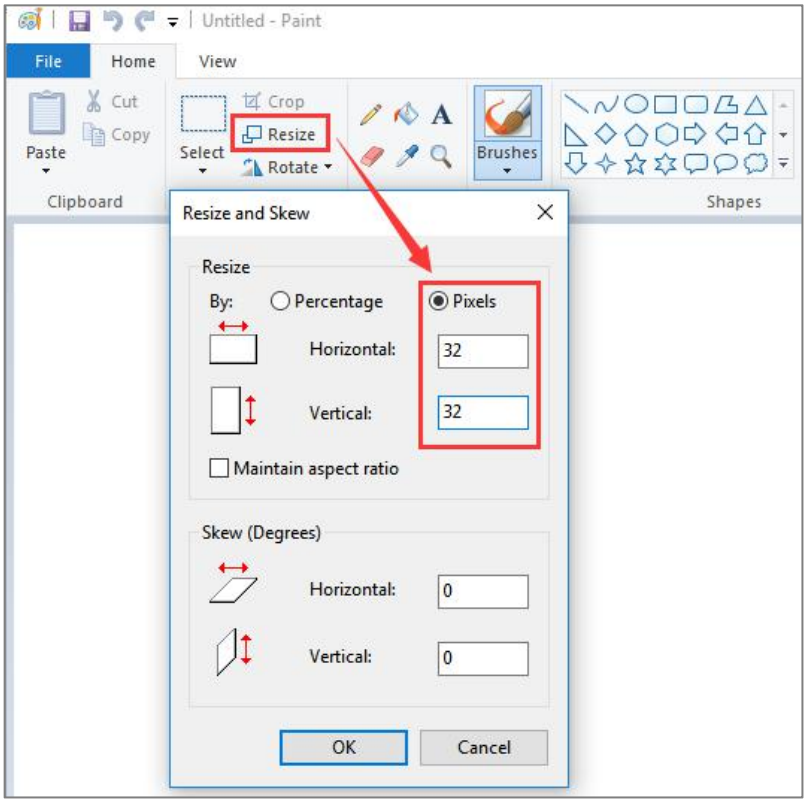
```
distances: [17.80449381 15.5241747  13.74772708 ... 11.61895004 16.76305461
 16.30950643]
sortDistance: [1370  607  653 ...  455 1390 1537]
The classification result is:5,  The real result is:5
distances: [15.09966887 19.84943324 19.33907961 ... 18.22086716 17.60681686
 19.67231557]
sortDistance: [ 242  199  415 ...  509 1724 1155]
The classification result is:0,  The real result is:0
distances: [15.29705854 17.08800749 15.93737745 ... 16.85229955 14.69693846
 16.64331698]
sortDistance: [1332  248  419 ... 1761  393   33]
The classification result is:8,  The real result is:8
distances: [16.24807681 15.29705854 13.56465997 ... 13.03840481 14.49137675
 18.52025918]
sortDistance: [1156    8 1791 ...  989  917 1683]
The classification result is:5,  The real result is:5
distances: [16.30950643 15.68438714 15.03329638 ... 16.24807681 12.
 17.29161647]
sortDistance: [ 485  539 1007 ...  393  862  853]
The classification result is:2,  The real result is:2
Total number of errors:12
Error rate:0.012672
[5]:  12.0
```

2.Recognizes handwritten number

Steps to make a handwritten digital picture:

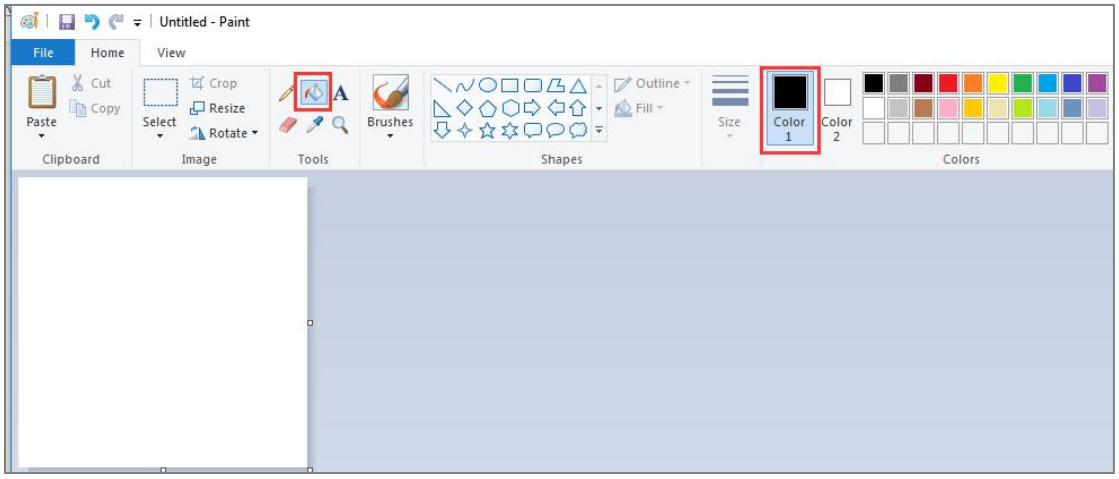
①Open the drawing software, adjust the resolution to 32*32, and other resolutions are also possible, but it is best to the picture can fill the entire interval.

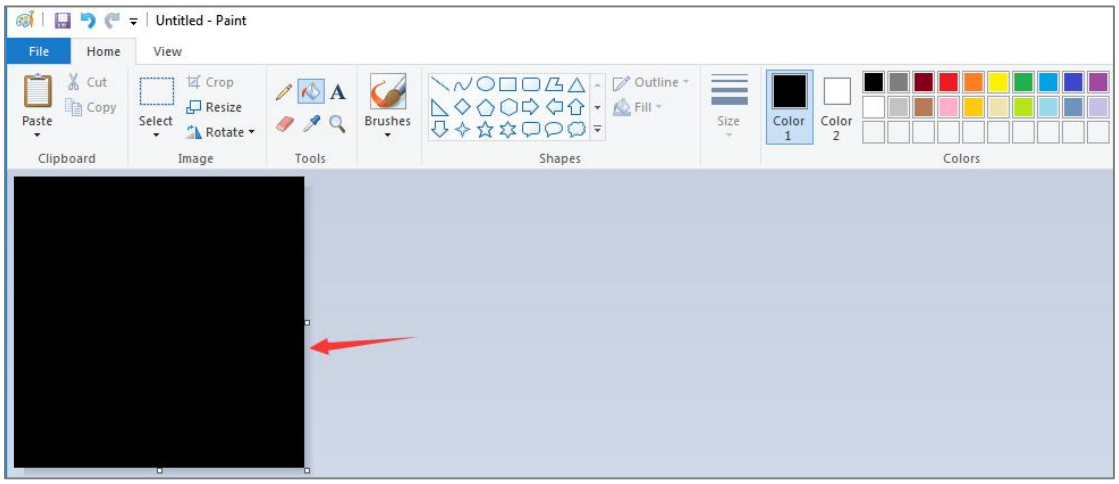
As shown below.



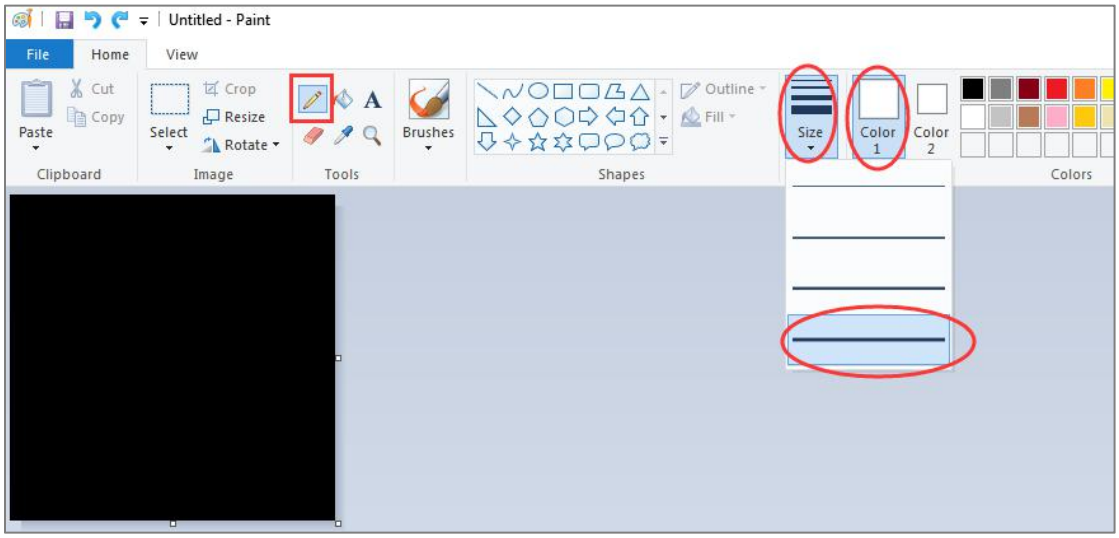
【Adjust the resolution】

②Press “ctrl” and the mouse wheel slides up to enlarge the picture to the maximum. Select the paint bucket tool and select the black color to fill the entire screen.

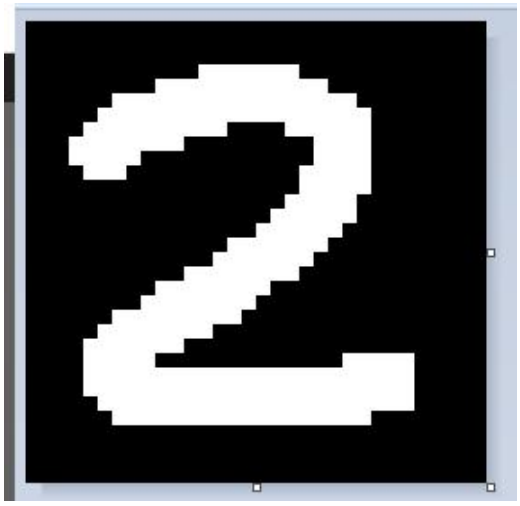




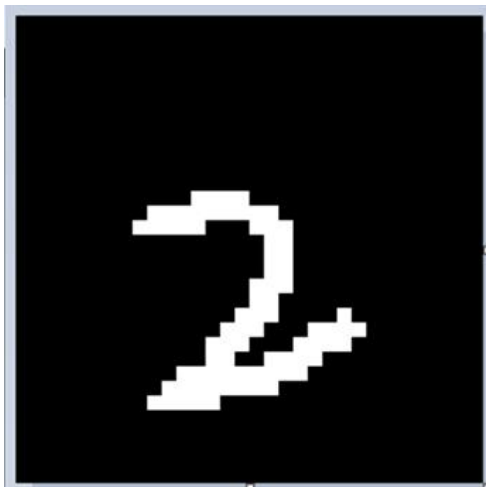
③Choose the pencil tool, choose white for the color, and choose the maximum width for the line thickness. As shown below.



④We can write a number, it need fill the entire area.

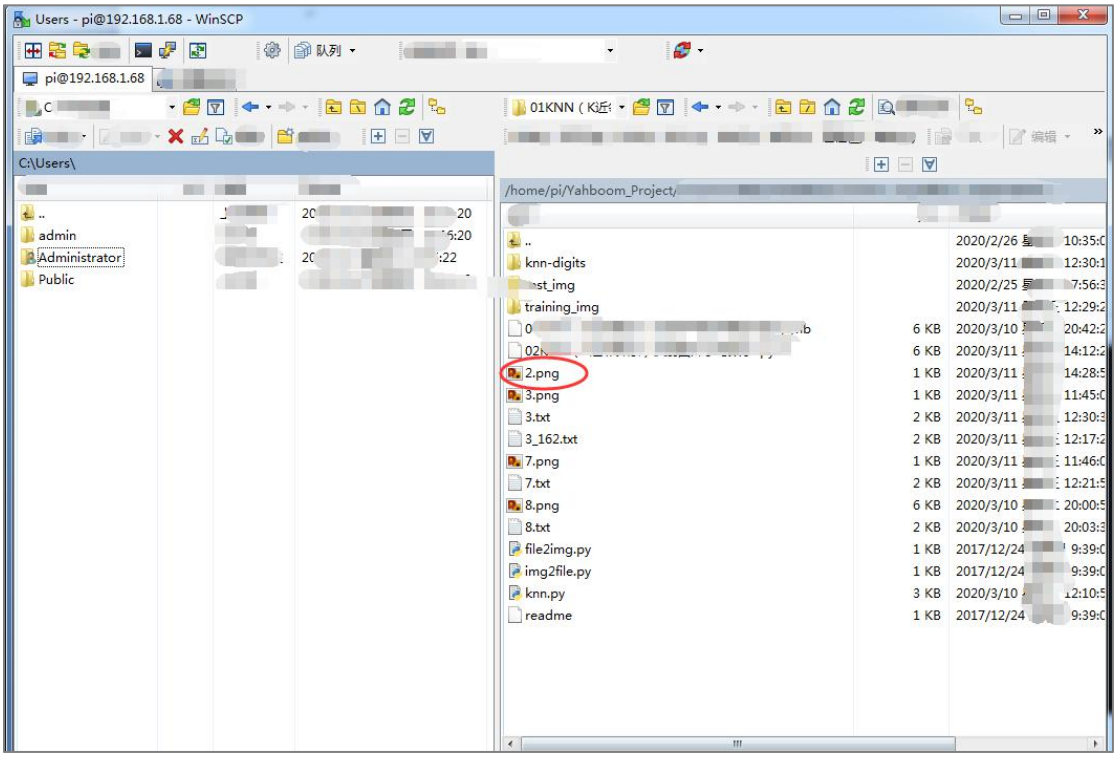


【Correct example】



【Wrong example】

⑤After drawing, save it as a png image and copy it to the project directory using WinSCP tool.



Code path:

/home/pi/Yahboom_Project/1.OpenCV_course/05machine_learning/01KNN/KNN_2.ipynb

Code as shown below.

```
#!/usr/bin/env python3
```

```
# -*- coding: utf-8 -*-



import numpy as np

import operator

import os
```

```
# Convert image data to (1,1024) vector

def img2vector(filename):

    returnVect = np.zeros((1, 1024))

    file = open(filename)

    for i in range(32):

        lineStr = file.readline()

        for j in range(32):

            returnVect[0, 32 * i + j] = int(lineStr[j])

    return returnVect
```

```
# KNN Classifier

def classifier(inX, dataSet, labels, k):



  # numpy shape [0] return the number of rows in the array, shape [1] returns the number of columns

    #MDS

    dataSetSize = dataSet.shape[0]

    #The inverse matrix
```

```
    diffMat = np.tile(inX, (dataSetSize, 1)) - dataSet

    #Two-dimensional features are subtracted first and then power

    sqDiffMat = diffMat ** 2

    #Calculate distance

    sqDistances = sqDiffMat.sum(axis=1)

    distances = sqDistances ** 0.5

    print ("distances:",distances)

    #Returns the index of the elements in distance sorted from small to large

    sortedDistIndicies = distances.argsort()

    print ("sortDistance:",sortedDistIndicies)

    classCount = {}

    for i in range(k):

        #Take out the first k element categories

        voteIlabel = labels[sortedDistIndicies[i]]

        classCount[voteIlabel] = classCount.get(voteIlabel, 0) + 1

    #reverse

    sortedClassCount = sorted(classCount.items(), key=operator.itemgetter(1), reverse=True)

    return sortedClassCount[0][0]
```

```
#Convert image data to txt file



from PIL import Image
```

```
"""
    Convert image data to txt file
    :param img_path: path of image
    :type txt_name: Output txt file path
"""
def img2txt(img_path, txt_name):

    im = Image.open(img_path).convert('1').resize((32, 32))    # type:Image.Image
    data = np.asarray(im)
    np.savetxt(txt_name, data, fmt='%d', delimiter='')
```

```
#Convert the image to a 32*32 array

img2txt("3.png", "3.txt")
```

```
#training part

hwLabels = []
trainingFileList = os.listdir('knn-digits/trainingDigits')
m = len(trainingFileList)
trainingMat = np.zeros((m, 1024))
for i in range(m):
    fileNameStr = trainingFileList[i]
```

```
        fileStr = fileNameStr.split('.')[0]
        try:
#                 if(fileStr.split('_')[0] == ''):
#                         continue
#                 else:
                classNumStr = int(fileStr.split('_')[0])
        except Exception as e:
                print('Error:', e)


        hwLabels.append(classNumStr)
        trainingMat[i, :] = img2vector("knn-digits/trainingDigits/%s" % fileNameStr)
```

```
# Recognize handwrite classification results


fileStr = "2.txt"
classNumStr = int(fileStr.split('.')[0])
vectorTest = img2vector("./2.txt")


result = classifier(vectorTest, trainingMat, hwLabels, 3)    # k=3
print("The classification result is:%d, The real result is:%d" % (result, classNumStr))
```

After running the program, we can see the results shown in the figure below.

```
distances: [18.24828759 18.78829423 17.74823935 ... 19.46792233 15.84297952
 18.22086716]
sortDistance: [1434  751  593 ...  853 1618  393]
The classification result is:2, The real result is:2
```

！ Note:

If the recognition result is different from the real result. Please copy the converted txt file to knn-digits/trainingDigits/, and name it as follows: 2_201.txt, and then re-train, it will can work normally.