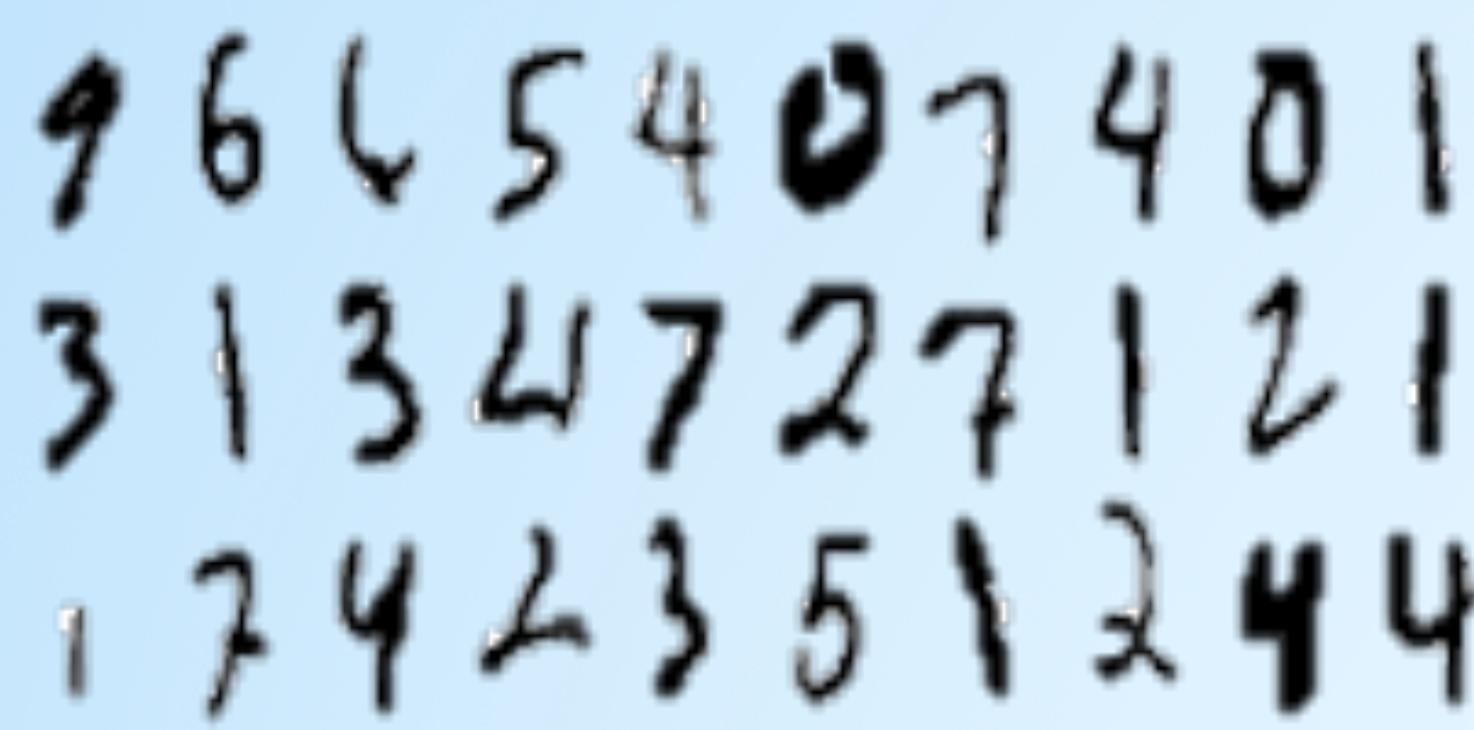




# Digits Recognition

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## Introduction

Nowadays, people usually use laptop to type document, but what if we want to convert and recognize handwritten into document editor. It can save a lot of time to type by ourselves again. The goal of this project is to take an image of a handwritten single digit, and determine what that digit is. To make this goal achievable, we provide several different machine learning algorithms and help you to get started, which are K-means, Naïve Bayes, BP Neural Networks and K-nearest Neighbors.

## K-means

kmeans clustering is a method of vector quantization, originally from signal processing, that is popular for cluster analysis in data mining. k-means clustering aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster.

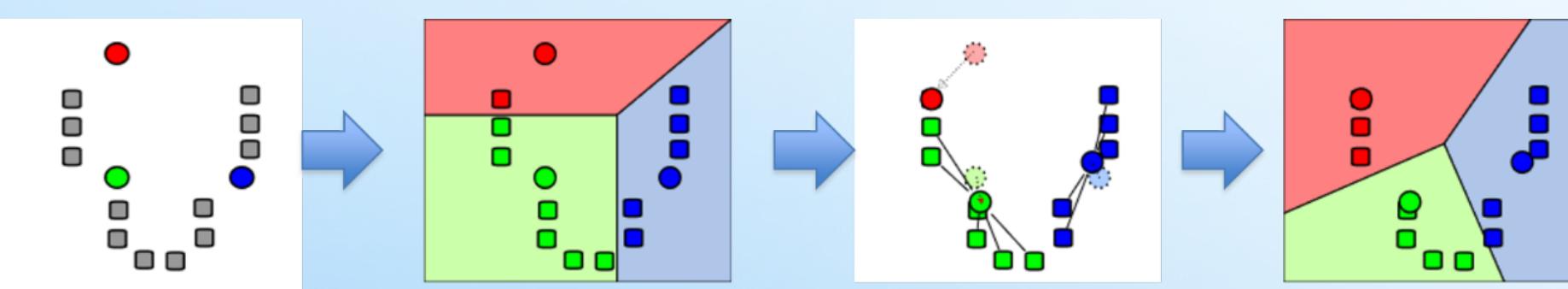


Figure 1. A demonstration of the standard algorithm

The steps of the standard algorithm is shown as follows. In the first step, k initial "means" ( $k=3$  in Fig.2) are randomly generated within the data domain (shown in color in Fig.2). Secondly, k clusters are created by associating every observation with the nearest mean. Then the centroid of each of the k clusters becomes the new mean. At last, steps 2 and 3 are repeated until convergence has been reached.

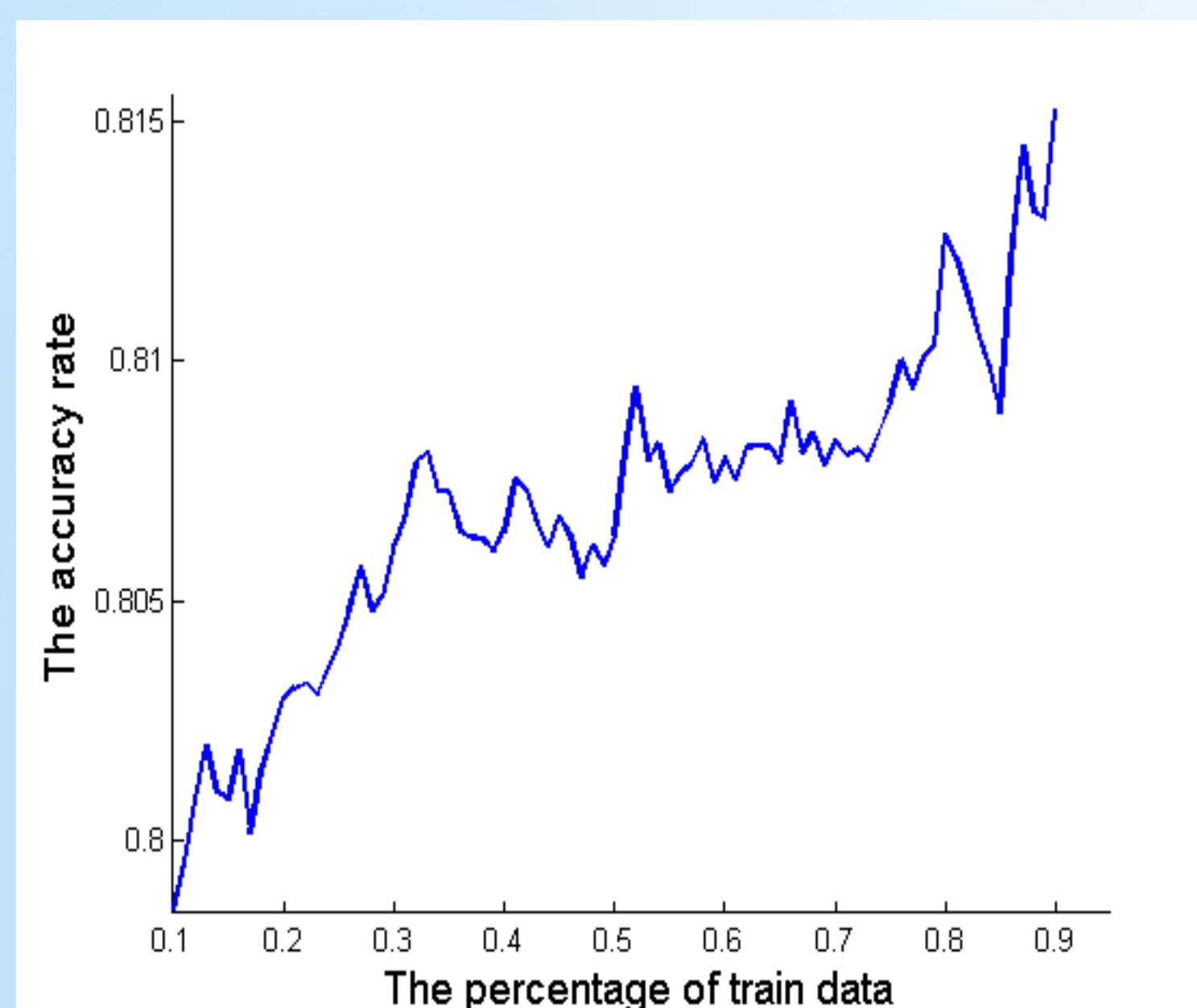


Figure 2. The relationship between the percentage of training data and the accuracy rate

It can be found that the accuracy rate is stable around 80% and increase slightly with the increase of the percentage of training data. It is found that the k-means is an effective algorithm. In this problem, it only takes 7.12 seconds to obtain the calculation results, which is extremely fast comparing with other algorithms. we can come to the conclusion that although the k-means is an effective algorithm, it cannot perform well in the problem of digit recognizer because of the low accuracy.

## Naïve Bayes

Singular Value Decomposition of the training data set gives the first nine principal component of MNIST Database of handwritten digits as shown in Figure 3. And the corresponding singular value plotting is shown in Figure 4. The 2nd, 3rd and 4th features of training data set is plotted Figure 5.

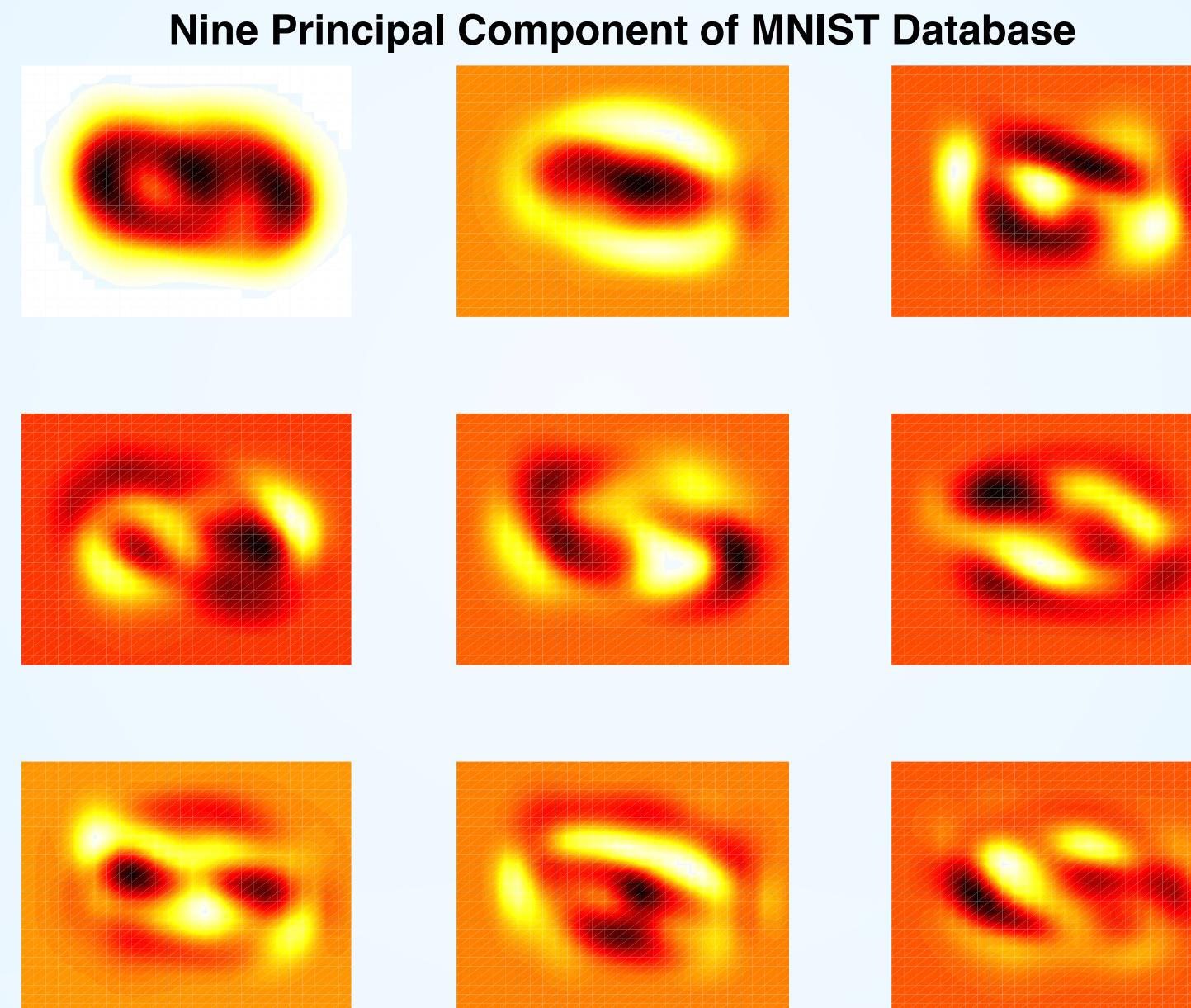


Figure 3. Principal Component of handwritten digits from the last 80% of training data set

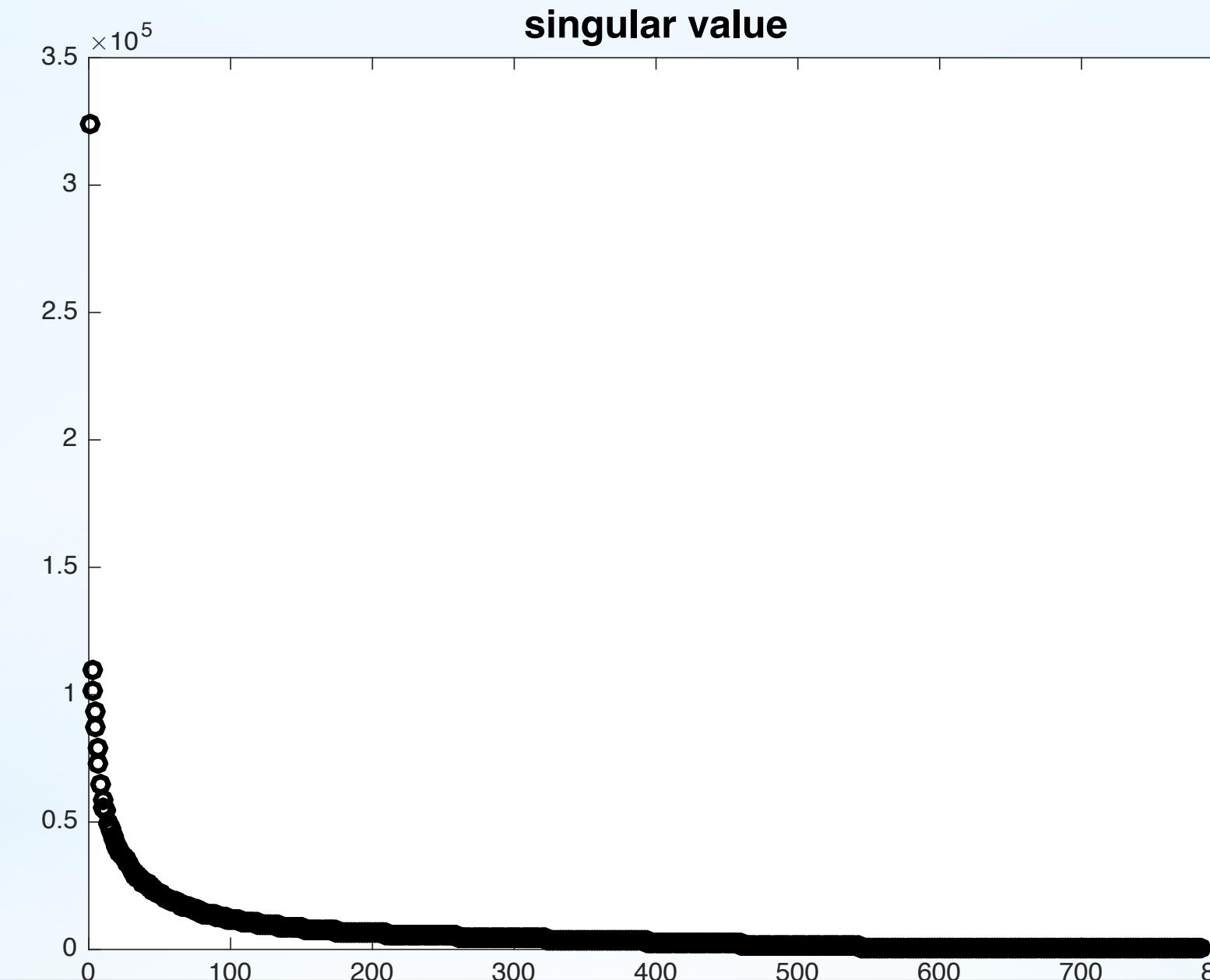


Figure 4. Singular value plot of handwritten digits from the last 80% of training data set

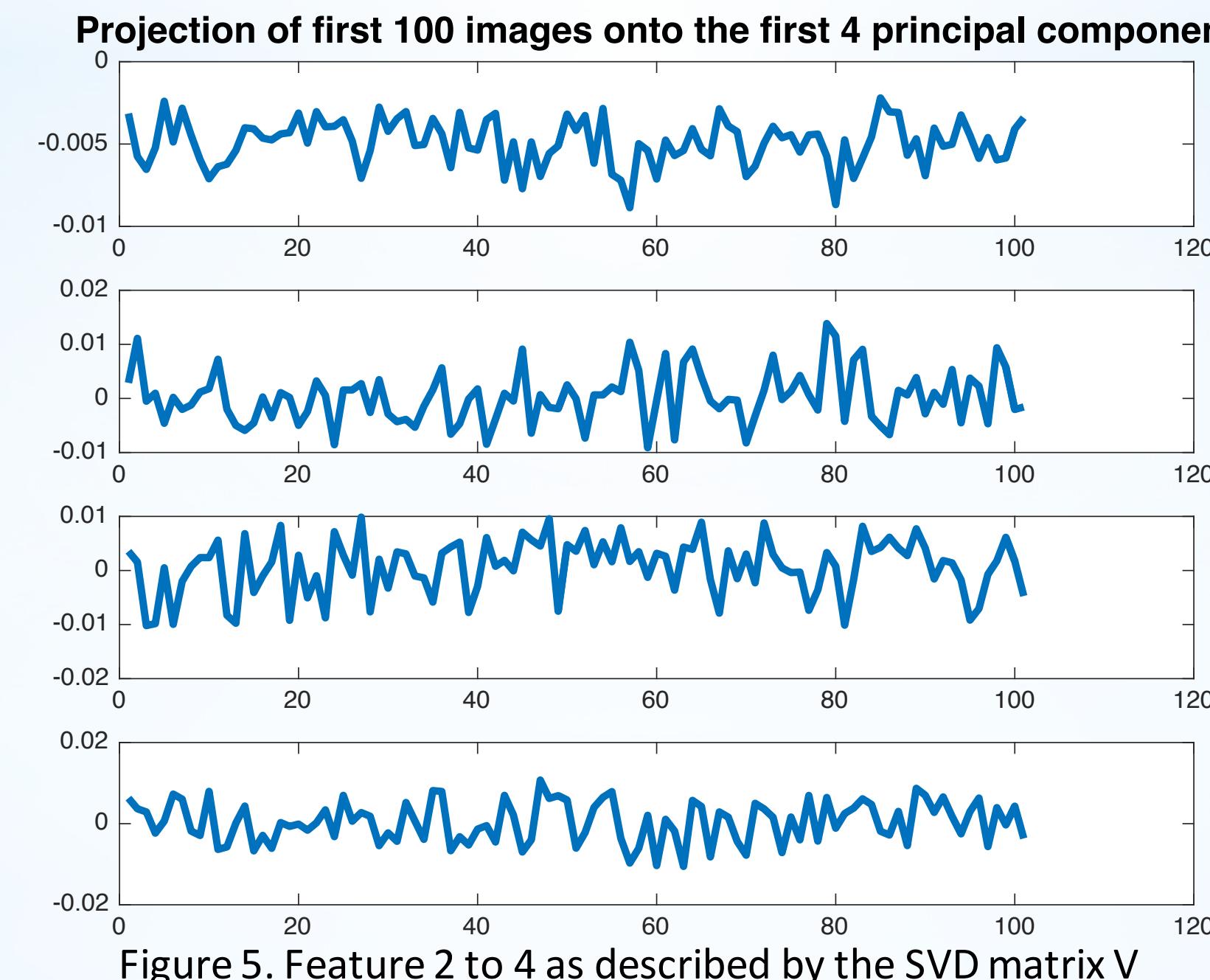


Figure 5. Feature 2 to 4 as described by the SVD matrix V

It is one of supervised methods for machine learning and easy to construct without using any iterative parameter estimation schemes. Besides, Naïve Bayes is proved to be robust and can be applied to many machine learning problems[1]. The recognition accuracy given by Naïve Bayes in our digit recognition problem is 86.76%, which is surprisingly well since we did not even optimize the algorithm for this certain problem and its data set. Linear Discriminant Analysis (LDA): It is a method used in machine learning to find a linear combination of features that characterizes or separates two or more classes of objects or events. The resulting combination would be used as a linear classifier in our problem. The recognition accuracy given by LDA in our digit recognition problem is 85.87%.

## BP Neural Networks

Back propagation neural network is one kind of neural networks with most wide application. It is based on gradient descent method which minimizes the sum of the squared errors between the actual and the desired output values. The structure is showed in Figure 6

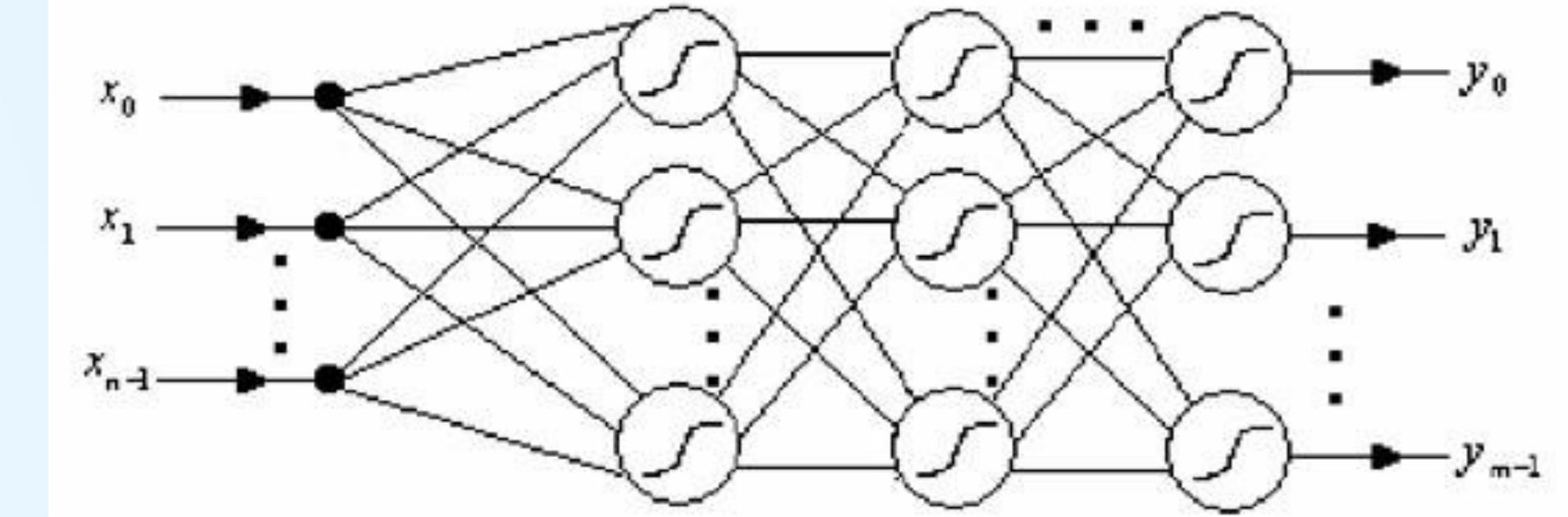


Figure 6. Structure of BP neural networks.

The overall data is 42000 and we use 41000 of it to train the system and use left 1000 to test the BP neural network. After training, the BP neural network can recognize 87.7% of digital number.

## K-Nearest Neighbors

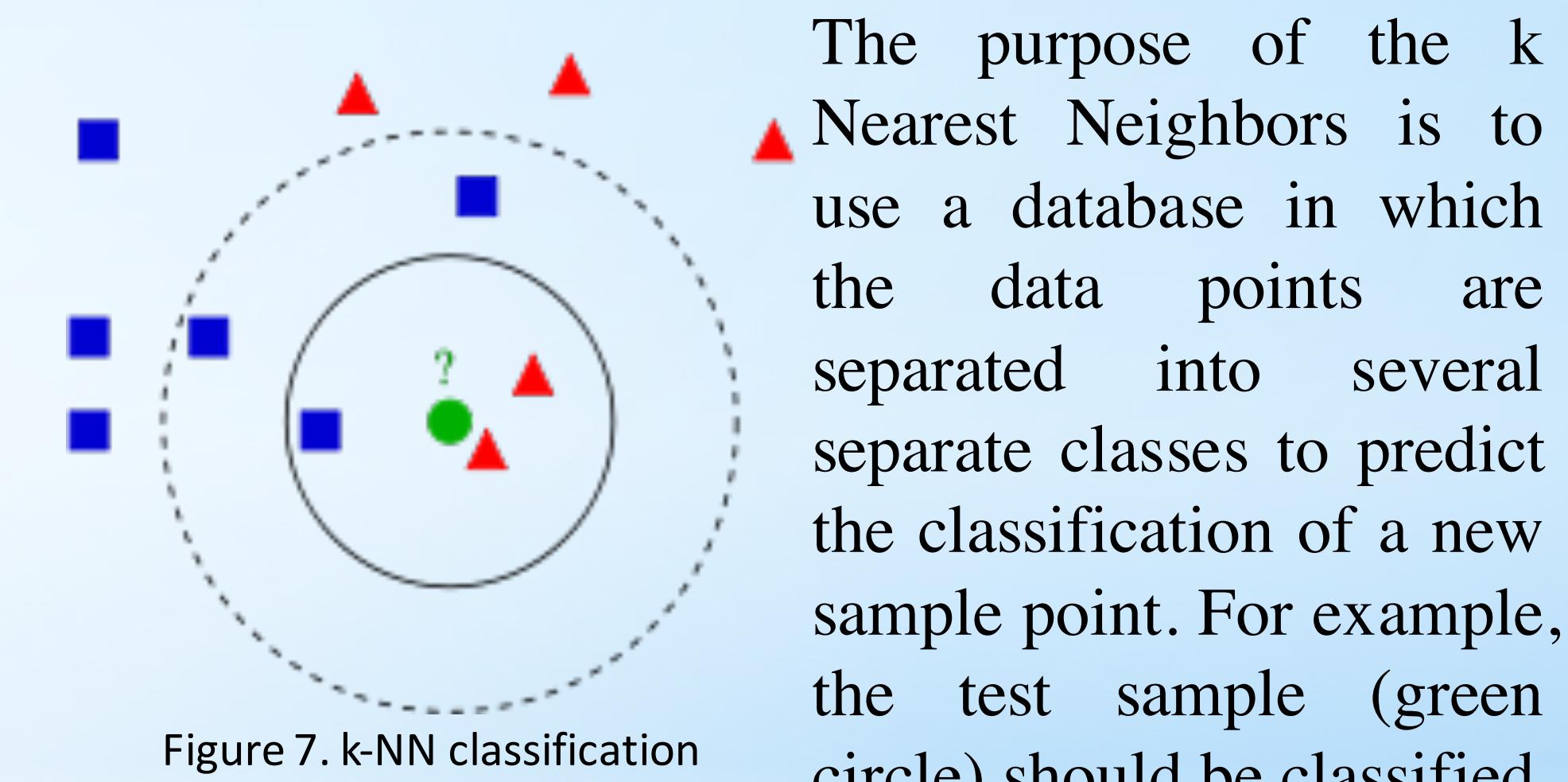


Figure 7. k-NN classification

The purpose of the k Nearest Neighbors is to use a database in which the data points are separated into several separate classes to predict the classification of a new sample point. For example, the test sample (green circle) should be classified

The test sample (green circle) should be classified either to the first class of blue squares or to the second class of red triangles. If  $k = 3$  (solid line circle) it is assigned to the second class because there are 2 triangles and only 1 square inside the inner circle. If  $k = 5$  (dashed line circle) it is assigned to the first class (3 squares vs. 2 triangles inside the outer circle), shown as above Figure 7. In our project, 80% of the data were used to train the system and rest 20% to test the K-NN Algorithm. By using this method, the error is 7.82%, which means it can recognize 92% of digits but it takes 1956seconds to classify the entire data.

## Conclusion

In this digits recognition project, we used several machine learning algorithms, which are K-means, Naïve Bayes, BP neural networks and K-Nearest neighbors. To compare these algorithm, the more error caused, the more time takes. So we need to choose the method by balance the correctness and time spending. This algorithms all have relatively low error to test the data and they are the basic way to recognize digits. For deeper application, we based on this method can not only recognize the handwritten numbers but also recognize word, characters and symbols.

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