Fruit Image Classification Based on SVM, Decision Tree and KNN

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Abstract: Image classification is becoming more and more popular in today's daily life. Image classification is widely used in many fields. For example, the market demand for face recognition technology has increased significantly in recent years. The foundation of these new technologies is still image classification. In order to explore the efficiency of different image classification algorithms and help guide the use of different image classification algorithms in the market, this paper uses a variety of algorithms to classify images in the fruit360 dataset. Fruit360 dataset is a dataset with 90483 images of 131 kinds of fruits and vegetables. Images in this dataset have a size of 100×100 pixels. As a result, the Support Vector Machine algorithm is 89% accurate, the decision tree algorithm is 94% accurate, and the K-nearest Neighbors algorithm is nearly 100% accurate. Apart from the accuracy of these algorithms, this paper also analyzes the difference in classification accuracy among different classes. For the Support Vector Machine algorithm, the classification accuracy of class 1 and class 2 is low, which is caused by the algorithm itself. For the decision tree algorithm, the accuracy of each classification group is similar. For the K-nearest Neighbors algorithm, the overall accuracy is very high. In addition, this paper also compares the characteristics of these three algorithms, analyzes the performance difference between the Support Vector Machine algorithm and the decision tree algorithm, and discusses the relationship between the Support Vector Machine algorithm efficiency and the number of classes.

1 INTRODUCTION

Nowadays, image classification is widely used in people's daily life. Taking the campus as an example, schools need to use a face recognition system at the entrance of the library to help determine whether there is access permission. But the author sometimes sees such cases: some people outside the school can also successfully pass the face recognition system. This means that the current image classification still has the problem of low accuracy. In this paper, SVM, decision tree and KNN, three different algorithms are used, and based on fruit360 dataset, various classification algorithms are compared and analyzed, so as to give a reasonable method selection for image classification problems.

There have been many scientific studies based on these algorithms. Boumedine Ahmed Yassine et al. used KNN for 3D face recognition. They used KNN for feature extraction (Yassine et al 2023). In other research, they did glass component classification based on decision tree (Guo et al 2023). However, most of the existing research lack the comparison between algorithms.

In addition, there are many research on image classification using neural networks (Zhang et al 2014). However, a neural network is an end-to-end model, which remains a "black box" for users, and people cannot intuitively see the operation process of its internal algorithms (Wang et al 2020)0. Also, the training time of neural network algorithm is long, and the interpretation is not strong enough. So this paper focuses on the SVM, decision tree and KNN algorithm.

Support Vector Machine is a supervised machine learning algorithm, and it is widely used for regression and classification tasks (Chandra and Bedi 2018 & Nie et al 2023). In addition to image classification, SVM can be applied to text classification, such as sentiment analysis, topic classification, etc. SVM can extract text features and make decisions for classification. SVM can also be used for financial forecasting. In the financial field, SVM can be used to predict stock prices and calculate the risk of investments.

The decision tree algorithm is used in the financial field and medical field. In the financial field, banks can use a decision tree model to predict a customer's

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credit rating by taking factors such as a customer's personal information and historical loan history. In the medical field, the decision tree algorithm can be used for disease diagnosis, drug therapy, etc. For doctors, they can use decision tree models to predict the situation of a patient by taking plenty of factors such as symptoms and other indexes.

A machine learning approach called K-nearest neighbors may be applied to tasks involving regression and classification (Soucy and Mineau 2002). For speech recognition, it can classify audio signals into different speech or voice types by analyzing and comparing those given data. As long as the scene meets the standard classification or regression problem, it can try to use the KNN algorithm to solve it. However, it should be noted that the main disadvantage of the KNN algorithm is high computational complexity, especially when the data set is large, and the calculation distance requires more time and computing resources.

In this paper, the author uses various methods, including SVM, decision tree and KNN, to finish this image classification task. By using different algorithms for image classification, the differences of different algorithms on this task would appear. Using a variety of evaluation indexes to estimate the efficiency of different algorithms.

2 METHOD

2.1 Dataset Analysis

In this section, the author will have a brief introduction to the dataset. The name of this dataset is "fruit-360", which means that it has a large quantity of fruit images. So here, the author first calculates the amount of images in the folder. There are 90483 images in the dataset. The training set contains 67692 images and the test set contains 22688 images. There are 131 classes of fruits. Fig. 1. shows some pictures in the dataset in Jupyter Notebook.

To simplify the problem, only 10 classes of fruits were used for image classification. Doing this can reduce the expense of time, which can highly develop the efficiency of evaluating different algorithms.

2.2 Data Preprocessing

By fetching images from the given folder, the author imports pictures into Python for further classification. Using Python to get those folders' names and list them in an array. Then, with a random rate of 100%, the original training data are divided into 2 sets. The training set accounts for 80% and the test set accounts for 20%.

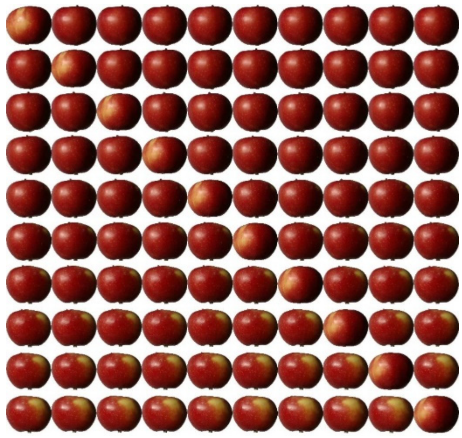

Figure 1: Some Pictures in the Dataset (Picture credit: Original).

After that, by resizing images, they are adjusted to the same scale. Then calculate the image histogram for further preparation.

2.3 Support Vector Machine

Support Vector Machine is a data-based classification algorithm, which focuses on establishing a hyperplane to divide data.

By finding the best hyperplane in space, SVM could reach a result that the distance between positive samples and negative samples is the farthest. In binary classification, SVM could be a line in a 2-dimensionality figure. It can also be used in a n-dimensionality question, where n is larger than 2. Fig. 2 shows the utilization in solving binary classification problems (Guo et al 2023) and Fig. 3. shows the utilization in solving 3-dimensionality problems.

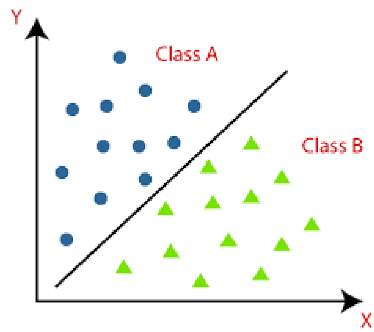

Figure 2: SVM Principle (2-dimensionality).

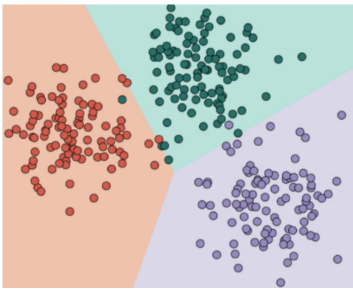

Figure 3: SVM Principle (3-dimensionality).

2.4 Decision Tree

The decision tree algorithm is a method of approximating discrete function values. It is an algorithm with a tree structure, and each point means an attribute for judgements. Leaves refer to a classification result. By using decisions, the decision tree algorithm can analyze data using readable rules.

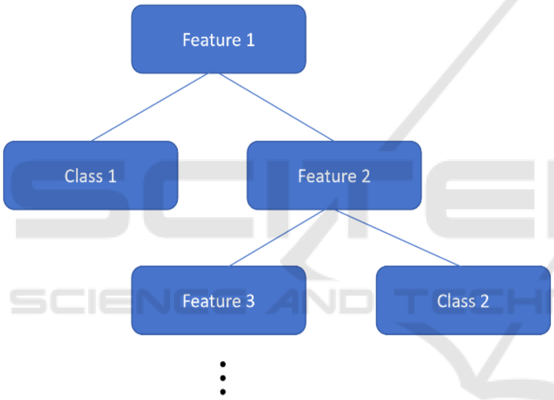

Figure 4: Train of Thought of Decision Tree (Picture credit: Original).

The decision tree algorithm is a common supervised learning algorithm. By determining whether the input data has a label, people can know whether it is supervised learning. If the input data is labeled, it is supervised learning. In this task, the data set is given labels for different pictures, which can be seen as supervised learning. With supervised learning, the model can use previous experience for evaluating the output result, and the accuracy of prediction can be high.

The train of thought of decision tree is shown in Fig. 4.

2.5 K-Nearest Neighbors

For classification problems, K-Nearest Neighbors is an efficient technique that may be applied broadly. The K-nearest data points may be used to forecast a specific query point, and the labels of these neighbors can then be used to predict the query point. In classification tasks, the predicted label for query points is determined by the weight of those K-nearest neighbors. The KNN algorithm can also be used for text classification. By extracting the features of words, the text is classified according to different dimensions (Li 2021).

2.6 Evaluation

By calculating the value of Accuracy, Precision, Recall and F1-score, the rationality of the algorithm would be evaluated. Also, by using the test dataset and calculating the probability of correct classifications, the model can be proved to be practical or not. During programming, by automatically generating the result of Precision, Recall and F1-score, the accuracy of a certain model can be found, which is helpful for evaluation.

Confusion matrix is an important tool for supervised learning. It is a form, which contains rows representing the practical classes and columns representing the predicted classes. Each cell expresses the frequency in a certain state. By analyzing the confusion matrix, the accuracy of the model will be further indicated.

Accuracy reflects the proportion of those true predictions for positive and negative examples. When a model has a high level of accuracy, it means that the amount of correct prediction is large. Using (1) can calculate the value of accuracy.

$$Accuracy = \frac{TN + TP}{TN + TP + FN + FP} \quad (1)$$

Precision can reflect the proportion of accurate predictions based on all predictions. It shows the proportion of actual predictions in all positive samples. Equation (2) shows the process of calculating the value of Precision.

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

The process of calculating Recall can be explained by (3).

$$Recall = \frac{TP}{TP + FN} \quad (3)$$

F1-score is a comprehensive evaluation index for evaluation, which is based on Precision and Recall. If a model has a high F1-score, it would be balanced, which means that one of the values of Precision and Recall would not be too high. F1-score can be calculated by (4).

$$\frac{2}{F_1} = \frac{1}{Precision} + \frac{1}{Recall} \quad (4)$$

3 RESULT

3.1 Runtime Environment

The environment for these algorithm is Jupyter Notebook 6.6.4. All the code is run on a Dell Inspiron 7400 laptop, with 11th Gen Intel® Core™ i7-1165G7 @ 2.80GHz CPU and Intel® Iris® Xe Graphics GPU.

3.2 SVM Result

Using SVM for image classification, and results are shown in Table 1.

Table 1: SVM Result.

No.	Precision	Recall	F1-score	Support
0	0.52	0.58	0.55	106
1	0.69	0.71	0.70	87
2	1.00	1.00	1.00	99
3	1.00	1.00	1.00	91
4	1.00	1.00	1.00	87
5	1.00	1.00	1.00	92
6	1.00	0.97	0.98	92
7	0.99	0.98	0.98	100
8	0.94	0.84	0.89	113
9	0.89	0.88	0.88	83
accuracy	-	-	0.89	950
macro avg	0.90	0.90	0.90	950
weighted avg	0.90	0.89	0.90	950

The confusion matrix is shown in Fig. 5.

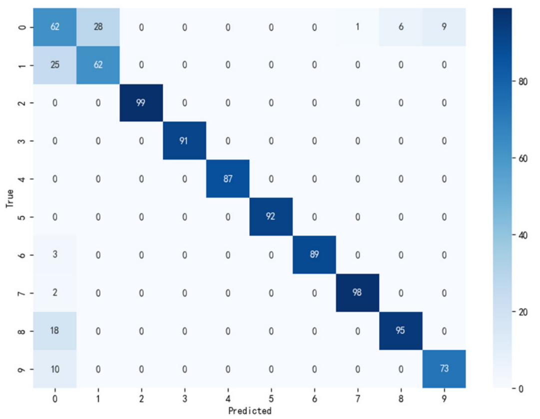

Figure 5: Confusion Matrix for SVM (Picture credit: Original).

Code execution time: 386.26s.

The SVM algorithm requires a long time to finish this image classification challenge. There are some reasons for this:

- When the scale of the dataset is large, the distance between each sample point and all other sample points needs to be calculated, which causes the computational complexity to increase dramatically as the number of samples increases.
- When dealing with non-linear problems, SVM requires kernel functions to map primitive features into higher-dimensional Spaces. This process can lead to computational complexity, making the training process slow.
- Binary classification problems were the initial purpose of SVM's creation. Various binary classifications are necessary when handling various classification problems. This process can lead to increased computational complexity, making the training process slower. This aspect will be discussed in the discussion part of this paper.

There are some characteristics in Fig. 5. In Fig. 5., class 0 and class 1's results are not as good as expected. Some pictures in class 1 are classified as class 2, and some pictures in class 2 are classified as class 1. It is inferred that there is little difference between class 1 and class 2 in image data features, which leads to an inaccurate result. Also, due to the fact that images from class 0 and class 1 are quite similar to images from class 8 and class 9, which leads to misclassification.

3.3 Decision Tree Result

Using the decision tree algorithm for image classification, the results are shown in Table 2.

Table 2: Decision Tree Result.

No.	Precision	Recall	F1-score	Support
0	0.94	0.84	0.89	106
1	0.96	0.98	0.97	87
2	0.95	0.98	0.97	99
3	0.98	0.95	0.96	91
4	0.94	0.95	0.95	87
5	0.97	0.95	0.96	92
6	0.95	0.95	0.95	92
7	0.91	0.96	0.94	100
8	0.92	0.93	0.93	113
9	0.93	0.98	0.95	83
accuracy	-	-	0.94	950
macro avg	0.94	0.95	0.94	950
weighted avg	0.94	0.94	0.94	950

The confusion matrix is shown in Fig. 6.

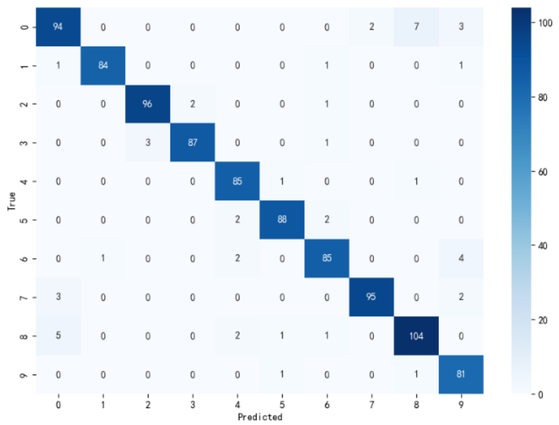

Figure 6: Confusion Matrix for Decision Tree (Picture credit: Original).

Code execution time: 25.34s.

In Fig. 6., the accuracy of different classes is very close. There is no longer a phenomenon that the classification accuracy of some groups is very low as in the results obtained by the SVM algorithm. Consider that this effect is caused by image noise.

Superfluous information in photographs is referred to as image noise. Image noise can be defined as any variety of elements present in image data that may impede individuals from making accurate decisions. Image noises are random and unpredictable. Usually, while acquiring a picture, image noise data are produced. The working environment is often the cause of image noise. Circuit construction and electronic components may also be to blame. Image noise can occasionally be produced as a result of pollution that occurs during media transmission and recording equipment.

In Fig. 6., each group has a margin of error, which means they have something in common. Due to the limited number of image pixels in the dataset, the prediction accuracy cannot be further improved.

3.4 KNN Result

Using KNN for image classification, the results are shown in Table 3.

Table 3: KNN Result.

No.	precision	recall	f1-score	support
0	0.99	1.00	1.00	106
1	1.00	0.99	0.99	87
2	1.00	1.00	1.00	99
3	1.00	1.00	1.00	91
4	1.00	1.00	1.00	87
5	1.00	1.00	1.00	92
6	0.99	1.00	0.99	92
7	1.00	1.00	1.00	100
8	1.00	1.00	1.00	113
9	1.00	0.99	0.99	83
accuracy	-	-	1.00	950
macro avg	1.00	1.00	1.00	950
weighted avg	1.00	1.00	1.00	950

The confusion matrix is shown in Fig. 7.

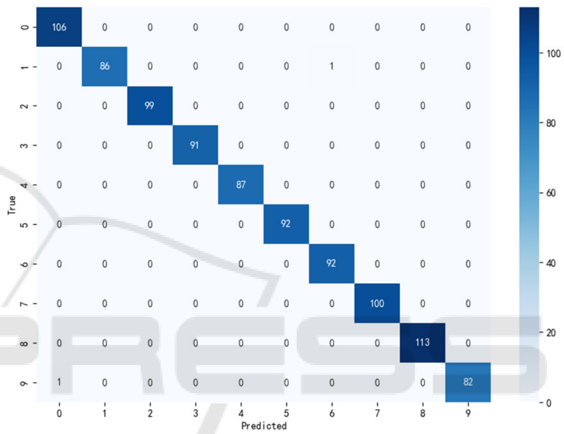

Figure 7: Confusion Matrix for KNN (Picture credit: Original).

Code execution time: 14.20s.

In Fig. 7., the accuracy of KNN is quite high. In the experiment, merely a few data have wrong prediction results. KNN can handle classification problems, and it can naturally handle multiple classification problems compared with SVM. The accuracy of the KNN algorithm is improved by finding the appropriate K value through loop traversal. Therefore, the classification results of the KNN algorithm can be interpreted more accurately from the perspective of its characteristics.

3.5 Classification Result Evaluation

There is a significant variation in algorithm efficiency in Fig. 8. SVM is more time-consuming than KNN and decision trees. The SVM algorithm's performance generally declines as the number of classes increases. It was initially created to solve binary classification problems.

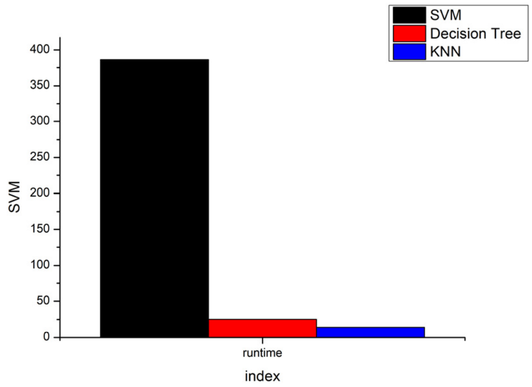

Figure 8: Classification Runtime (Picture credit: Original).

Compared to SVM and the decision tree algorithm, SVM needs to find the optimal hyperplane to distinguish data during training, which requires repeated calculations until a hyperplane satisfying the conditions is found. It can take a long time to complete this procedure, particularly when working with big datasets. In contrast, in the training stage, the decision tree algorithm simply uses a rectangle to divide the feature space, so the decision tree algorithm has a relatively small calculation amount.

In contrast to SVM and KNN, KNN requires less computation and operates more quickly because it just has to store training data during the training stage and compute the distance between the sample to be predicted and the training data during the prediction stage.

3.6 Results for SVM Algorithm Efficiency

In order to find out the law between code execution time and the amount of classes, the author did further research on efficiency. By adjusting the amount of classes from 2 to 10, the result is shown in Table 4.

Table 4: SVM Runtime and Accuracy.

Num of classes	Runtime	Accuracy
2	7.73	0.97
3	17.43	0.92
4	53.00	0.91
5	65.34	0.91
6	117.26	0.90
7	147.65	0.90
8	282.63	0.91
9	323.07	0.91
10	356.27	0.89

4 DISCUSSION

4.1 Accuracy Differences Between SVM and Decision Tree

This may caused by the characteristics of SVM and decision tree. Image data usually has a large number of features, and the relationships between features can be very complex. SVM may have difficulty in dealing with high-dimensional features, especially when dealing with non-linear problems. In contrast, decision trees may be more flexible when dealing with nonlinear problems.

4.2 SVM Algorithm Operation Efficiency

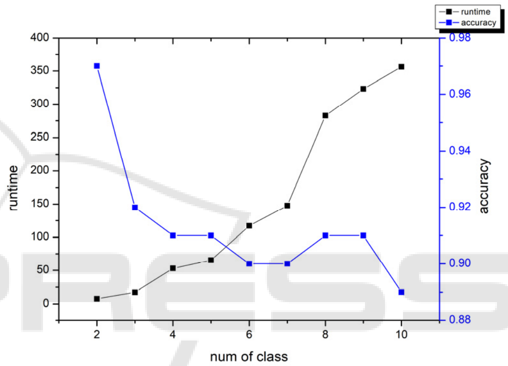

Figure 9: SVM Algorithm Operation Efficiency (Picture credit: Original).

In Table 4 and Fig. 9., the tendency of runtime and accuracy change over time. Also, there is an obvious increase when the number of classes rises from 7 to 8. These phenomena can explain the reason for the long time cost of using SVM in this image classification task.

5 CONCLUSION

For this image classification task, using SVM, decision tree and the KNN algorithm can acquire a precise result. These methods can be widely used in other image classification tasks by combining with other technology. If the algorithm listed in this paper is combined them with the camera, it can be used for the statistics of supermarkets. This will greatly improve the operating efficiency of the supermarket and reduce operating costs. However, there are still some details that need to be improved. Due to the limitations of those given data, future research needs to focus on enhancing algorithm accuracy. For example, add an analysis of some of the features of the image. By analyzing the texture of the image and the shape of fruit, the accuracy of the classification algorithm is improved.

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