Title:

Multiclass Apple Varieties Classification Using MachineLearning with Histogram of Oriented Gradientand Color Moments.

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Main points to notice:

- lower accuracy but good discrimination power

Our target:

- Increase accuracy

Summary:

1. Introduction

Apple is a well-known fruit species in the world, and is used in many products such as purees, chips, vinegar, teas, jams, marmalades, medicinal plants, and fruit juices. It is a type of fruit that is easily recognized and sought after by consumers based on its variety.

Figure 1. Average apple production for the year (1994–2021).

Precision agriculture is critical for maximizing the efficiency of agricultural methods, reducing the cost of production, and ensuring environmental safety.

Machine learning is used in several scientific disciplines, including plant taxonomy, botanical gardens, and the discovery of new species, to identify and categorize different species of plants. Image processing and machine learning are widely used to classify different apple varieties.

Several studies have shown that Naive Bayes has good potential for the identification of apple varieties nondestructively and accurately. Several studies have also shown that partial least squares discriminant analysis (PLSDA) models have potential for apple variety detection.

Patel and Chaudhari studied six types of fruit using thresholding and morphological processing and employed five different machine learning algorithms: KNN, SVM, Naive Bayes, random forest, and neural network to classify the fruits.

To identify the type of seasonal fruits and detect spoiled ones, researchers used color and texture features, KNN and SVM, and shape-based features. They used Naive Bayes and MLP classifiers, and Ghazal et al. used hue, color-SIFT, discrete wavelet transform, and Haralick features.

Researchers used color and texture features to classify ten fruit types, using HSV color space and a three-level discrete wavelet transform.

This study aims to develop an efficient and repeatable system for classifying ten apple varieties by extracting textural and color features from RGB apple images. It compares the performances of widely used ML algorithms to find the best-performing classifier.

2.1. Image Acquisition

Our study used ten apple varieties commonly grown in Turkey. A camera with a resolution of 20 megapixels was used to capture images, and all images were taken under the same light condition.

2.2. Image Features Extraction

Image feature extraction involves automatically identifying and extracting notable and meaningful information or representations from digital images. It is beneficial for various applications, such as object recognition, image retrieval, medical imaging, video surveillance, and other related tasks.

Multiple techniques are used for image feature extraction, including edge detection, corner detection, blob detection, and texture analysis. Color moments and a histogram of oriented gradient (HOG) were extracted from ten apple varieties.

Figure 3. HOG features extraction.

In HOG feature extraction, the histogram distribution of oriented gradients of neighboring cells is normalized and concatenated into a single feature vector.

Color moments are measures used to differentiate images based on the features of their color. These moments are used as inputs to train machine learning models.

2.3. Features Used for Training

The dataset in this work consists of 159 attributes and 5830 instances of ten (10) apple labels or classes.

2.4. Machine Learning Classification Models

Machine learning classifiers, namely support vector machine (SVM), random forest classifier (RFC), K-nearest neighbor (KNN) and multilayer perceptron (MLP) were trained and tested using the 144 HOG features and 15 color moments.

During the training, stratified cross-validation (Skfold) was applied, where data points of each class are proportionally distributed across the k-fold. This method gives a more reliable prediction and, eventually, better accuracy than the normal k-fold CV method.

2.5. Performance Measures

The performance of the classification algorithms was evaluated using metrics of accuracy, precision, recall, specificity, and F1-score.

To examine the trade-off between true positive rate and false positive rate, we used AUC-ROC and AUC-PR, and considered Cohen's kappa and MCC to assess the overall performance of the models.

The performance metrics were computed using the true positives, true negatives, false positives, and false negatives objects, as obtained from the confusion matrix of the classification results of every model.

3. Results

The classification models were trained using Scikit-learn and 10 Skfold were used to fine-tune the hyperparameters. The performance metrics are provided in Table 2.

The performance metrics of the four ML models are accuracy, precision, recall, specificity, F1-score, AUC-ROC, AUC-PR, Cohen's kappa, and MCC.

Figure 7. MLP confusion matrix.

Figure 8 represents the confusion matrix according to KNN, and shows that 18 instances of Red Braeburn were confused with Starkrimson.

Figure 8. KNN confusion matrix.

As detailed in each table above, Red Braeburn and Starkrimson are the most often confused with each other in all four models, likely due to their natural resemblance.

4. Discussion

In an attempt to recognize fruits and vegetables, KNN, linear discriminant analysis, Naive Bayes, error-correcting output classifier, and decision tree classifier were used. KNN achieved a classification accuracy of 97.5% with 2400 images from 24 categories of fruits and vegetables.

Researchers used machine vision to sort Golden and Starking Delicious, Granny Smith apple cultivars into different classes by their color, size, and weight. The system achieved an accuracy rate of 73-96%.

In related studies, shape-based features were used to classify seven fruit types with a maximum accuracy of 95% using the Naive Bayes classifier, and color and texture features were used to classify ten fruit types using an SVM classifier.

Researchers used HSV color space for thresholding and region of interest extraction, and extracted color features through hue and saturation. They used SVM to classify six fruit types, and achieved an accuracy of 91.67%.

Our method outperformed related results, likely due to the incorporation of color moments as an additional feature, which enhances the classification accuracy of apple varieties with increased classes.

According to the performance metrics, MLP and SVM are the best-performing models for this dataset, with accuracy, precision, recall, and F1-score values of 98.62%, 98.59%, 97.97%, and 98.48%, respectively. They also have high AUC-ROC and AUC-PR values, indicating good discrimination power.

5. Conclusions

Image processing and machine learning have been widely used in classifying apple varieties. The study demonstrated the potential of machine learning models for accurate and efficient classification of ten apple varieties, and could lead to improvements in the apple industry.