Advances in the Application of Image Processing Fruit Grading

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Abstract. In the perspective of actual production, the paper presents the advances in the application of image processing fruit grading from several aspects, such as processing precision and processing speed of image processing technology. Furthermore, the different algorithms about detecting size, shape, color and defects are combined effectively to reduce the complexity of each algorithm and achieve a balance between the processing precision and processing speed are keys to automatic apple grading.

Keywords: Image-processing, Computer-vision, Fruit Grading

1 Introduction

In the recent decade, most of the worldwide apple products are made in China. China produced 3598 million tons of apples every year, while the second-placed U.S.A has the production of 427 million tons. However, China still has a low export volume of apples, 103.47 million tons in 2011, accounts, only 2.87% of the yearly production. And it also is reduced by 7.86% year-on-year. By the investigation of the consequence, the first reason is the high quantity but low quality of products. Secondly, there is no any application which is efficient and high precision in grading apples, so the graded good quality apples are difficult to find in markets. At the last, the agricultural labor force is transferring to other industries in great quantities, the intelligent machine is needed to liberate human from heavy and monotonous work. The existing method of fruit grading can be divided into two categories, one is the mechanical classification and the other one is based on optical measurement device. The former one is mainly judged by hole or lever, the latter judge the diameter and size of fruit by photoelectric detector or test the surface color to judge the maturity. However, the fruit grading method based on machine vision has advances in the application. According to analyzing images by cameras, it is easily to calculate a lot of parameters such as area, diameter and so on. It can test size, color, defects and bruise in one time. In addition, the biggest advantage of machine vision grading is the high efficiency regardless of the influence of subject factor. Therefore, it is urgent to improve the technology of apple grading, especially the technology which can be applied to the actual production. For these, the paper reviews the apple grading technology in the world based on the image processing.

2 Research Situation

It is widely acknowledged that apples' size, shape, color and defects are concerned separately in the existing technology of grading apples. Under experimental conditions, the ideal accuracy and processing speed can be achieved. Consequently, the paper summarized the current technology inspecting the processing precision and speed.

2.1 Processing Precision

Miller developed a color computer vision system to inspect and grade peaches' surface. Digital color images of peaches were acquired as the fruit moved on a belt conveyor. Image analysis algorithms were developed to compare peach ground color to reference peach maturity colors estimating the amount of blushed surface area. Ground color maturity classification with the computer vision system agreed with manual maturity classification in 54% of the test samples, and was within one color standard in 88% of the samples. Correlation coefficient between machine and manual estimates of blush surface area was 0.92[1]. Leemans V. etc. presented a hierarchical grading method applied to Jonagold apples. Several images covering the whole surface of the fruits were acquired thanks to a prototype grading machine. These images were then segmented and the features of the defects were extracted. During a learning procedure, the objects were classified into clusters by k-mean clustering. The classification probabilities of the objects were summarized and on this basis the fruits were graded using quadratic discriminant analysis. The fruits were correctly graded with a rate of 73%. The errors were found in the segmentation of the defects or for a particular wound, in a confusion with the calyx end [2]. Devrim Unay etc. presented a novel application work for grading of apple fruits by machine vision. Following precise segmentation of defects by minimal confusion with stem/calyx areas on multispectral images, statistical, textural and geometric features are extracted from the segmented area. Using these features, statistical and syntactical classifiers are trained for two- and multi-category grading of the fruits. Results showed that feature selection provided improved performance by retaining only the important features, and statistical classifiers outperformed their syntactical counterparts. Compared to the state-of-the-art, their two-category grading solution achieved better recognition rates (93.5% overall accuracy). In this work, they further provided a more realistic multi-category grading solution, where different classification architectures are evaluated. Their observations show that the single-classifier architecture is computationally less demanding, while the cascaded one is more accurate [3].

Zhao Jing took the advantage of reference shape analysis and artificial neural network to identify and classify apples' shape, which improved the accuracy rate to 93%. On the basis of analysis of fruit shapes, 6 characteristic parameter is proposed to describe fruit shape, which include diameter, continuity, curvature and the symmetry of the former three-parameter[4]. Wang Jian etc. took different quality level apple color pictures by digital camera. Using R color branch to determine threshold value after image smoothing, they carried through image segment and erosion, then transferred RGB to HSL. At last, the true apple area was obtained by means of pixel points transform method taking count of the number of pixels on the projection. The results showed that the method was proper for the apple sorting based on computer vision, and it had a result with a veracity of 89.8% compared with manual judgment[5]. Rao Xiuqin etc. put forward a grading method to improve the quality of fruits. They made use of HIS color model to analyze the fruit image after segmentation and calculated the principal component (PC) of the H component histogram weighted by the fruit surface area. And then the average values of the most significant MPCs of the red and yellow sample groups were calculated respectively, which were used as the centers of the two sample groups to setup a grade model. A fruit was graded to the red group if the Mahalanobis distance between the fruit and the center of the red sample group was less than that between the fruit and the center of the yellow group, or it was graded to the yellow group. The test results of 800 navel orange images showed that the first and the second PCs of the H component histogram weighted by the fruit surface area were enough to grade a fruit, and the total error was only 1.75% [6]. Liu Yanglong studied the fruit shape classification. Wavelet descriptor is extracted to describe the fruit shape from wavelet transform of the normalized fruit radius sequence. Matching rates of different wavelet and different number of coefficients are analyzed on the reconstruction of the fruit border. The dimensions of shape feature are reduced using kernel principal component analysis (KPCA). The research shows that fruit shapes can be describe well by 36 points of Biorthogonal wavelet transform. Matching ratio between the shape and the reality is 98.64%. Finally, dynamic nearest neighbor-clustering algorithm is used to make the radial basis function (RBF) neural network as fruit shape classifier. The results show that the classification accuracy is 90% while the superior fruit recognition rate is 93.75% among the experiment. Experiments between wavelet descriptor and Fourier descriptor are compared[7]. Further, Li Junliang researches the relationship between the external features such as size color shape texture and internal quality of sugar. BP neural network and SVM (Support Vector Machine) are adopted to establish sugar classification model according to external features. The result shows that external features and internal quality of sugar have complicate non-linear relation. The accuracy rate of SVM is 82% which is higher than 64% of BP neural network classification model. At last, principal component features were extracted out from the NIR (Near Infrared Reflection) spectrophotometer as apples' internal features. Then outward features and internal features were fused with SVM to constructed sorting model of apples' sugar. The result shows that the sorting model with fusion technology is 91% better than the model with single sensor [8].

In the process of apple image detection, the largest factor which affects the precision is miscalculation of fruit stalk and calyx. Because of similarity of the fruit stalk, calyx and defects in the image, it is easily judge for defects. P.Jancsok proposed a new method to identify stem-end/calyx from bruises. According their method, a hyper spectral imaging system was used for separating stem-end/calyx regions from true bruises. Based on principal component analysis (PCA) of the hyper spectral images, multiple effective wave bands were selected. Afterwards, PCA and image-processing techniques were applied to the multispectral images. The stem-end/calyx regions were identified and distinguished from the cheek surfaces by analyzing the contour features of the first principal component score images. None of the sound tissue was misclassified as a stem-end or calyx region for both cultivars apples. In the investigated samples, all of the stem-end/calyx presented in the images were correctly recognized for the 'Golden Delicious' apples and 98 33% for 'Jonagold' apples. Les s than 3% of bruises were misclassified as stem -end/calyx regions for both cultivars apples [9]. Zhang Wenying etc. did something similar. According to the characteristics of apple stem, they used block scanning to judge stem. In addition, they found out the damaged area as well as stem and fruit calyx by analyzing the different reflection characteristics of the damaged surface and healthy surface, and the statistical properties of different gray level value of pixel points. It was 100% accuracy rate on 15 fruit stalk pictures, while the accuracy of 90 stem picture was 88%. Experiment results proved that the method for detecting detected surface is efficient [10]. Song Yihuan etc. proposed a method to distinguish the apple stem/calyx and defect based on DT-CWT (Dual Tree Complex Wavelet Transform) and LS-SVM (Least Squares Support Vector Machine). They took apple image decomposition with DT-CWT and constructed feature vectors with the mean and variance of the transformed high frequency subband coefficients, then classified with LS-SVM. After the experiment on 180 apple images, the result showed that it had the best effect of extracting texture features with wavelet decomposition classifying by means of 3 layers DT- CWT to 64*64 image. The accuracy rate was 95.6% [11]. The hyper spectral imaging technology was proposed to detect the subtle bruises on fruits by Zhao Jiewen. Apples were adopted as the experimental object. The apples hyper spectral images between 500 nm and 900nm wavelength were analyzed via the principal components analysis，and the feature images under 547nm wavelength were selected to detect the bruises on apples. The asymmetric brightness of the images was eliminated with asymmetric second difference subsequently. Finally， the feature of bruise was extracted through appropriate image processing. The experimental results show that detecting subtle bruises on fruits on1ine with hyper spectral imaging technology is realized and the accuracy is 88.57%[12].

2.2 Processing Speed

Li Qingzhong etc. proposed a fast approach for box-dimension estimation based on a dual-pyramid data structure. For the suspicious defect area in fruit images, they utilized traditional fractal dimension and 4 oriented fractal dimensions as input values. They calculated with the proposed fast calculation method, and then a BP neural network was designed for identifying fruit defect area and stem, calyx concave area. Test results proved that the rate of correct classification is 93% and the executing time of microcomputer for recognition of one undefined blob on the surface of apple is 4~7ms[13]. Shen Mingxia etc. adopted fuzzy threshold segmentation to process the original image. The process time of this method in 68 s, while the Ostu method uses 123 s. Obviously, the speed of this method had its advantage [14]. In the light of the characteristics and requirement of real-time inspection and grading, the continuous area-scans approach was put forward to acquire the image of fruits from time to time in a time-series manner by Huang Yonglin etc. The test results verified that this system could grab 12 frames per second with the triggering from the proximity sensors[15].Zhang Feng etc. selected roundness, volume and the gray-level histogram of R G B component as apple quality evaluation index. They calculated roundness and volume by apple binarization image. Compared the index of images' each R G B grayscale histogram with the standard apple, it can automatically detect appearance and quality of apples. It costs 0.9s to detect an apple which satisfied the requirement of the real-time detection. This technique can be used for the apple packaging product line, and also can be used for appearance quality detection of agricultural products similarly [16].

2.3 Combined with Processing Accuracy and Speed

Feng Bin etc. set up a standard sphere gray model, which can realize fruit defect segmentation. In addition, they used the single threshold while the threshold boundaries don't need to be considered. For recognition of stem, calyx and defect, they made full use of the influence of its space shape to gray feature, using Fourier transform to determine shape of gray line, which become a satisfied result. After identified 50 stems and 50 calyxes, the accuracy was higher than 90%. This method had a small amount of calculation and fast speed, which can meet the requirement of the computer vision on-line detection of fruit [17]. Zhang Yajing etc. proposed a method using intensity and color information for separating adjoined apples. Firstly, they used Lab model to segment apple image, followed by each segmented area was calculated to judge whether they were adjoined area or not. After calculating the light information within adjoined area, the segment adjoined area according light spot produced by brightness, which can shield the noise outside the area. However, the unique brightness information in the area can be utilized to segment adjoined apples effectively. Experimental results showed that the recognition rate was more than 92.89%, and it was simple and rapid. Furthermore, the average image recognition time was less than 0.5 s [18].

3 Conclusions and Prospect

In conclusion, since scholars have done a number of researches on apples during a long time, which comes various new algorithms and application methods. However, in practice, there is still a lot details to be improved. Therefore, the mainly problems of existing technology and the future direction of development can be summarized as the following points:

(1) Single detection feature. The existing technology always aims at detecting one single feature such as shape, weight, color or defeats. However, we prospect to grade in the minimum times of detection that we can improve production efficiency in the work site. Therefore, we would like to obtain enough information at one time.

(2) Balance between speed and accuracy. It is able to reach the ideal detection speed and accuracy under laboratory conditions, but either can meet the actual production requirement. Therefore, we need to reduce the complexity of the existing algorithm, yet we should not have much influence on the accuracy, which we must find a balance between speed and accuracy.

(3) We can consider using color image processing techniques because of the diversity of apples' surface color. Under these color images, it will be easier to judge stalk and calyx, avoiding mistaken for surface defects, as well as the apparent color and defects. Above all, the speed is still the problem to be solved yet.

(4) The lack of suitable mechanical structure for mass processing. Since most of the existing technologies are basically carried out under laboratory conditions, yet there are many uncertain factors in the process of production, thus we need to work out the suitable mechanical structure for image processing which makes the produce conditions as close as possible to the laboratory conditions.

In conclusion, simplifying the existing algorithms and fusing different detection algorithm to form higher speed and higher precision detection algorithm is the development direction in future image processing technology in practical production, which is supported by appropriate mechanical structure.

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