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Design Of Apple External Multi-Quality Detection System Based On Image Processing

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Abstract:
This paper studies the comprehensive detection and classification of various appearance quality characteristics of apples. In defect detection, the texture features of the region of interest were extracted and the support vector machine model was established. The classification of calyx area and defect area of fruit stem has been realized with an accuracy rate of 96.0%. In size detection, the maximum transverse diameter of the fruit diameter plane was calculated by comparing the length width ratio of the minimum circumscribed rectangle to find the fruit diameter plane. For the evaluation of fruit shape, the circularity method and the transverse longitudinal diameter ratio method were fused to features based on pre-set weight values, and then the final results were exported. For color evaluation, the color quality was reflected by calculating the red coloration rate through the H channel, which was validated to be suitable for different samples.

Key Word*: Apple; Machine vision; Interactive interface; Multiple features; Image processing*

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I. Introduction

Apple is the main consumption fruit in many countries [1]. Unfractionated apples are not easily achievable for categorical packaging, storage and transportation. More importantly, it is not easy to sell them according to their quality. Traditional computer vision system supports objective, economics, repeatable and accurate evaluation of food quality, and was also an effective technology for detecting the external quality of apples[2]. In industrial applications, the color, size, weight and defects of apples are usually the characteristics used to judge their quality [3]. Rapid and nondestructive methods based on machine vision had great advantages in the field of grading fruit detection because of low cost and rapid detection. Meanwhile, it has greater advantages in online detection and grading of common external quality of fruits and vegetables [4]. Not only the non-destructive detection of various quality characteristics could be achieved without contacting the detection target, but the precise and efficient detection grading could also be realized by synthesizing the multi-faceted appearance characteristic qualities such as size, color, defects and fruit shape of fruit.

For size detection, in the 3D coordinate-based method, Hayrettin et al. obtained the binary image of apples based on CIE Lab color space, counted the total number of pixels in the apple region, then judged the size of the apple based on the number of pixels [5]. Sofu et al. obtained images of the apple from four different angles, calculated the number of pixels at the maximum diameter in the horizontal and vertical directions respectively, and comprehensively evaluated the size of the apple based on the obtained eight parameters [6].

In the aspect of color detection, Mendoza et al. compared the effects of using different color models for fruit color detection, and finally found that Lab color model performed better in fruit color detection compared with RGB, HSV [7]. Prabha and Kumar extracted the average color intensity from the histogram, area and perimeter of the calibration image, then the algorithm was improved. The accuracy of maturity detection was evaluated to be 99.10% and 85.00%, respectively [8]. Pereira proposed a method to predict ripening of papaya fruit using digital imaging and random forest algorithm. The color feature was calculated from the pericarp with low calculation cost, and the accuracy was 94.30% [9].

For shape detection, Xu et al. used the K-means algorithm to classify the shape of strawberry and evaluated the shape of strawberry by fitting the curve using K-means clustering method, and the classification accuracy reached 90.0% [10].

In defect detection, the key problem is how to distinguish the defective parts correctly and prevent non-defective areas from being misjudged. Unay et al. extracted texture, shape and statistical features of defection regions and non-defection regions, which were input into five different classifiers for classification respectively. It was found that the classification model with support vector machines (SVMs) achieved the highest identification accuracy of 99% and 100% for the fruit stalk and calyx parts, respectively [11]. Mohana used support vector machine classifier to extract the shape features of the detected objects and identify the stem and calyx regions from the defects [12]. Moallem identified the peduncle region based on morphological method and Mahalanobis distance classifier, and the calyx region was identified using K-means clustering based on the Cb component image in YCbCr color model [13].

It could be seen from the above review of fruit quality inspection that the research for apple classification based on single feature was relatively mature. However, due to the diversity of organisms, there are great differences between apples of different varieties, or even among individuals of the same kind from different origins. The same detection index can not always meet detection requirements for different users. Therefore, the optimal detection method and standard should be established for apples of different varieties. Then, we can switch detection methods freely according to the actual situation to achieve high flexibility in detection. So it was extremely necessary to adapt the detection to different hierarchical needs in practical applications and thereby improve the flexibility of detection.

II. Material And Methods

Image acquisition system

The image acquisition system was a dark box with light source inside, which could effectively block the external light source and provide a ideal lighting environment. As shown in the structural diagram (**Fig.1**), a USB2.0 industrial camera and LED strip plate light source was used in this paper. In order to make the light relatively uniform when it reaches the apple center and edge part then obtain a uniform lighting environment, four lower light sources provided normal lighting for the side of the apple and Two upper light sources provided supplementary lighting for the upper part of the apple.

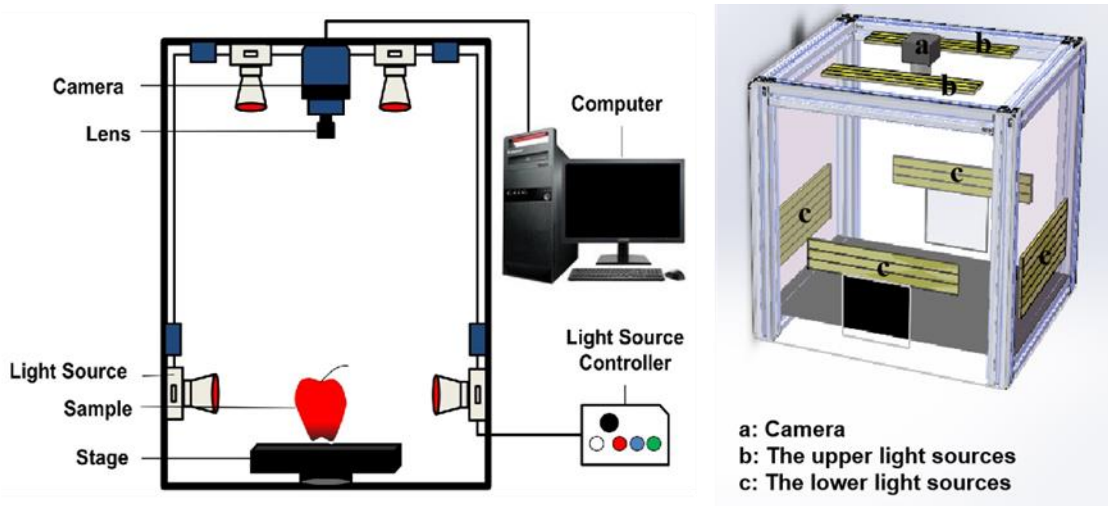


Fig.1 Image acquisition system

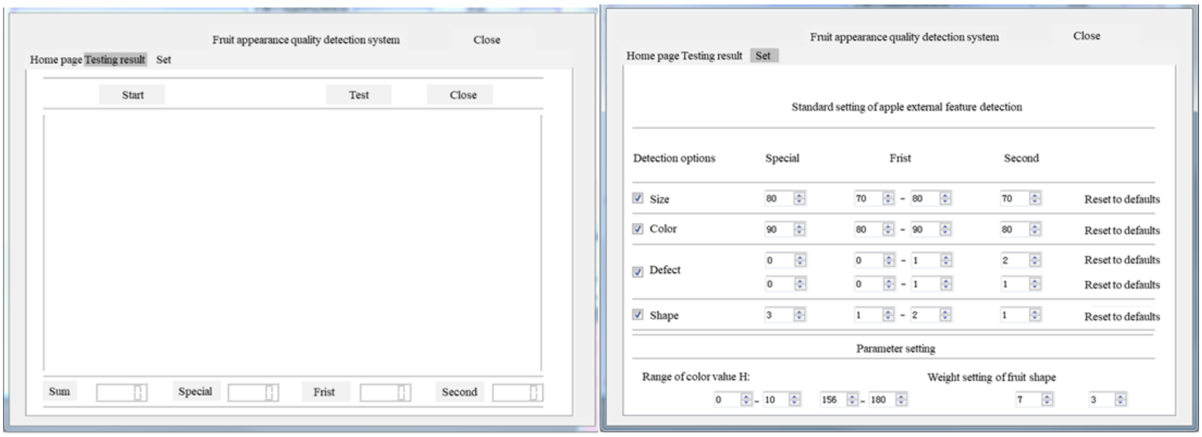
Interactive interface

The interaction interface includes detection hierarchical algorithm layer and human-computer interface interaction layer. The detection and classification algorithm layer mainly includes the algorithm logic design of image processing after apple image acquisition, feature extraction and classification result fusion output. The layout design and the connection between signal and slot were carried out in the human-machine interface interaction layer, which realized the information interaction between users and the system and fed back the running result of the algorithm at real time.

Interface layout design

In this paper, the QT Designer provided by PyQt was used to design the layout of the interface, which was shown in **Fig. 2(a)** and **Fig.2(b)**.

In this paper, the opposite-type Photoelectric sensor was used to acquire images. It could be triggered to take pictures of the apple when it was in detection position. The image display module was used for real-time display of apple images in the detection position inside the dark box. The result counting module was used to count the number of apples at each level after detection, then the detection information as size, defect, color, fruit shape was output on the status bar. The parameter adjustment module had the functional features of detection feature combination and adjustable detection method of detection standard range. Under the checked option, the range of evaluation criteria under each grade of apple could be adjusted up and down as needed.



(a) **(b)**

Fig.2 UI layout

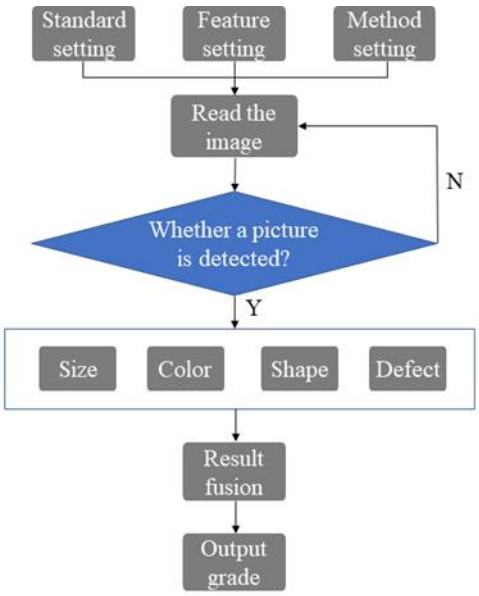


Fig.3 Algorithm flow

Detection algorithm flow design

The whole algorithm flow was shown in **Fig 3**. Before entering the assay, the required combination of detection features, range of binning criteria and key parameter settings was set by the users according to the actual application. Detection of the corresponding characteristic qualities is performed after reading the image to be detected into a detection program. The lowest grade of each characteristic quality was taken as the final result. The first class fruit judgment logic was that when all the detection results were judged as a special class fruit, the final output of the results was a special class fruit. The remaining cases were regarded as first-line results.

III. Plant material

The apple sample used in this experiment was Red Fuji. A total of 190 normal samples of apples were purchased at the fruit shop on the campus of Shandong University of Technology for size, color and shape tests and other 200 apples with defect were purchased for defect detection. All apples were cleaned and their actual diameter was measured and recorded before image acquisition.

Image segmentation

In order to reduce disturbance the influence of disturbance, background removal was performed with images of the apples. Firstly, RGB image was converted into HSV image and V-channel was separated. Secondly, binary image of apple was obtained as background separation template by threshold segmentation based on V-channel image. Lastly, the Otsu threshold segmentation was used to obtain the binary image of apples. During above process, some apples' pedicels, calyx and defect parts were perhaps wrongly treated. Therefore, a good binary image was finally obtained by using the hole filling method after threshold segmentation. In addition, the gray images of apples with background removed were obtained by using this template to calculate the threshold of the original image.

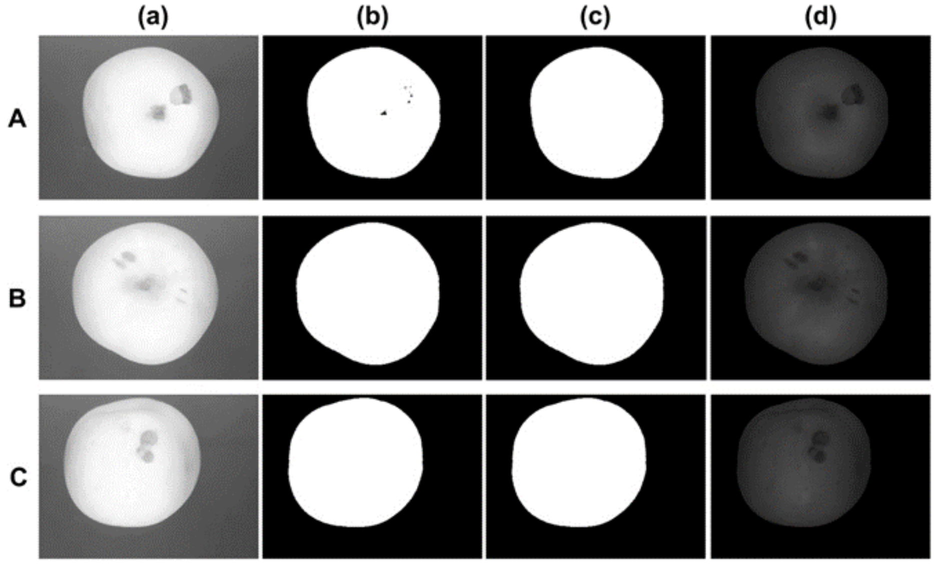


Fig. 4 Background separation process
(a) V channel, (b) OTSU threshold segmentation, (c) Hole filling, (d). Apple grayscale image with the background removed.

Multi-feature detection method

Size detection

According to the national standard GB/T 10651-2008 named "Fresh Apple"[14] of China, it was stipulated that the maximum cross-sectional diameter of an apple was the judgment standard for grading the size of an apple. Simultaneously, the maximum cross-sectional diameter which could be directly measured from the vertical view was the maximum diameter perpendicular to the fruit axis also is the line connecting the fruit stem and the calyx.

Zheng Yulun proposed an improved apple size detection method, by which the maximum cross-sectional diameter was measured according the vertical view. Firstly, the minimum enclosing Rectangle was drawn based on the maximum cross-sectional diameter. Secondly, the length-width ratio of the minimum enclosing rectangle was compared and the ratio nearest to 1 was determined to be the required fruit diameter for size judgement. Lastly, minimum circumscribed circle was drawn on its binary diagram and the diameter of the circle was determined as the diameter of the apple. However, the unit of the diameter obtained unit was pixel, and it should be converted to millimeter with the formula（1）as follow.

$$k = D/d \quad (1)$$

Where, d was the actual diameter(mm), D was the pixel diameter (pixel unit), K was the calibration coefficient.

Color detection

For requirements in apple color, the ratio of the pigmented area of the fruit surface was used as a grading basis. Therefore, the color feature was obtained by calculating the red coloration rate of the apple. The HSV model was more consistent with human visual characteristics compared with other colors pace model. In this model, the V component refers to the brightness, which is not related to color information.

The S component is the saturation, i.e. the shade of the colour, and the H component is the hue, which determine s the nature of the colour. However, only the color component as was H component needed to be detected because of fixed intensity of the light source. The threshold range of red in the H component was usually 0 to 10 and 156 to 180, of which the number of the pixels in the red area was computed. Then, the red coloration was determined based on the ratio of the number of pixels in the red area to the total number of pixels on the whole apple.

Defect detection

On the basis of distinguishing the stems/calyxes areas of the fruit from the real defect, the region of interest was extracted by brightness correction, median filtering, threshold segmentation, morphological operation and external rectangle on the images.

The suspected defect area was extracted and further judgment was performed to determine whether it was real defect or not. Textures could carry important information relation to the structure of physical objects [15]. The image was characterized by the fact that the dispersion of pixel brightness and texture and the repeated sub patterns of distribution reflect the spatial correlation of grayscale in the image [16]. Thus, classification was realized by extracting the texture characteristics of the defect and stems/calyxes area. GLCM could obtain comprehensive texture information reflecting image spacing, orientation, range of variation and speed [17]. The secondary statistical eigenvalues extracted from the GLCM were used as texture classification features. In this paper, four representative eigenvalues were selected for subsequent analysis: angular second-order moment (ASM), contrast (CON), entropy (ENT) and inverse difference moment (IDM). For training with small sample data, support vector machines (SVMS) tend to achieve better results than other algorithms. Thus, the texture features were extracted and input into SVM to complete the classification.

Fruit shape detection

The apple samples used in this experiment was Fuji, which was similar to the spherical. The ratio of the longitudinal diameter to the transverse diameter for roundness was used to evaluate and classify the shape of the spherical apples [18]. Roundness was calculated according to formula (2), which was used to determine the shape of an apple. When the roundness E is closer to 1, it means that the shape of an apple is approximate standard circle with minor difference between r_c and r_s. Otherwise, the larger the gap between the values of r_s and r_c, the more irregular the shape of an apple.

$$\mathrm{E} = \left(\frac{r_S}{r_c}\right)^2 = \frac{4\pi\mathrm{S}}{C^2} \tag{2}$$

The radius r_c and r_s. obtained under the circumference and area of the circle were shown in equations (3) and (4).

$$r_c = \frac{C}{2\pi} \tag{3}$$

$$r_S = \sqrt{\frac{S}{\pi}} \tag{4}$$

The method of ratio between horizontal diameter and vertical diameter was based on the minimum area of the circumscribed rectangle, whose width and length was used to indicate the horizontal and vertical diameters of an apple .Then the ratio between the horizontal and vertical diameters of the minimum circumscribed rectangle shown as formula(5) was used as indicator of the approximate circle of the apple.

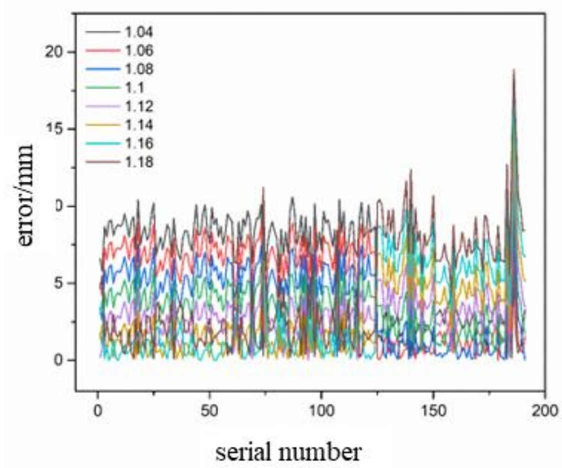
$$\mathrm{S} = \frac{W}{L} \tag{5}$$

Where, w(cm)was the width of the smallest circumscribed rectangle; L (cm)was the length of the smallest circumscribed rectangle; S was the fruit index. The closer the value was to 1, the closer the apple was to the standard circle.

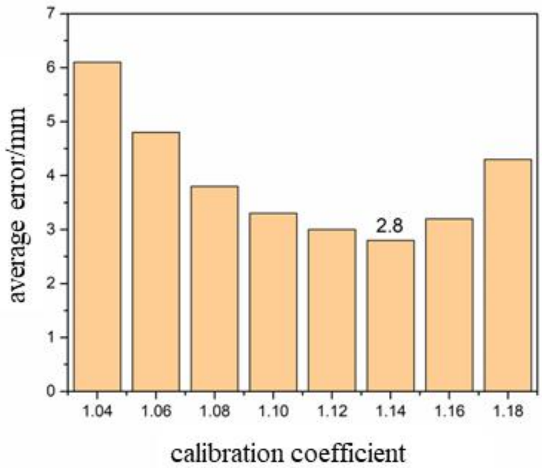
IV. Results and discussion

Size test results

190 apples were tested in this article. Apples with diameter of 70, 80 and 90 mm were randomly selected from all the samples. Simultaneously, the calibration coefficient range was tested and preliminarily determined to be between 1.04 and 1.18. Then the size of apples was measured under 8 sets of calibration coefficients respectively. The error between actual diameter and calculated diameter according to formula1 under different calibration coefficients from was shown in **Fig. 5(a)**. Meanwhile, the average error for all apples under these eight different calibration coefficients was shown in **Fig 5(b)**. It could be seen from the results that the average error achieved a minimum value of 2.8 mm under the calibration coefficient of 1.14. Therefore, the results of experiments met the 5% tolerance required in the standard and the accuracy was 92.6%. However, it could also be seen that there was obvious deviation between the actual and calculated diameter. The reason leading to this result was that the shape of individual apples varied greatly and the accuracy of individual deformed fruits was greatly affected when using this method to calculate.



(a)



(b)

Fig.5 Apple size detection results

Color test results

Firstly, the number of pixels in the red area of 0~10 and 156~180 under the H component and that of in the whole apple were measured. Then the ratio between the number of the above two pixels was used as red coloration. It could be seen form **Fig. 6(a)** that the red coloration achieved more than 99% and the surface of the apples was almost completely covered with red. Otherwise, it could be seen from **Fig.6(b)** that the red coloration achieved about 72% with some yellow area on the surface of the apple. Simultaneously, it could be seen from **Fig. (7)** that the red coloration achieved about 27% with less red area on the surface of the apples. Thus it could be seen that the higher the red coloration, the larger the actual coloration area of the apples. Meanwhile, the test method was proved to be useful.

Fruit shape test results

Comparison of apple images with different shapes, roundness, and aspect ratio was shown is **Fig.7**. It could be seen that apple in **Fig.7(a)** was the most regular and close to the circle, the apples in **Fig. 7(b)** was also more regular in shape, close to but slightly less than **Fig.7(a)**, and the apple in **Fig.7(c)** was the most irregular. The roundness of the three samples was 0.878, 0.847, 0.774 respectively. The closer the roundness was to 1, the more regular the shape was. Therefore, the calculation results conformed to the observed actual situation. The ratio of aspect ratio was 0.850, 0.857, and 0.774, respectively. The calculation results were consistent with the actual situation. However, the shape regularity of Sample 1 **(Fig.7(a))** and Sample 2 **(Fig.7(b))** was very close, and even Sample 2 **(Fig.7(b))** tended to be larger than Sample 1 according to this method.

However, there are still some differences between the judgment results of different methods, so it was necessary to consider combining multiple features for judgment to improve the accuracy of the results. In this paper, roundness and aspect ratio were combined to set the weight to judge the results and the judgment method was shown in the following Eq. (6). E_n and S_n were set as 3,2,1 when the apples were judged as first class, second class, third class respectively. The above values were substituted into Eq.(6) and A value obtained was between 0 and 3,which was used for the final classification result judgment. Evaluation was performed by the single method of ratio between longitudinal and transverse diameters or roundness when a was 0 or 1.

$$A = aE_n + (1 - a)S_n, \quad a \in [0,1] \tag{6}$$

Where, E_n was the circularity judgment result, S_n was the horizontal/vertical ratio judgment result, and A was the weight value.

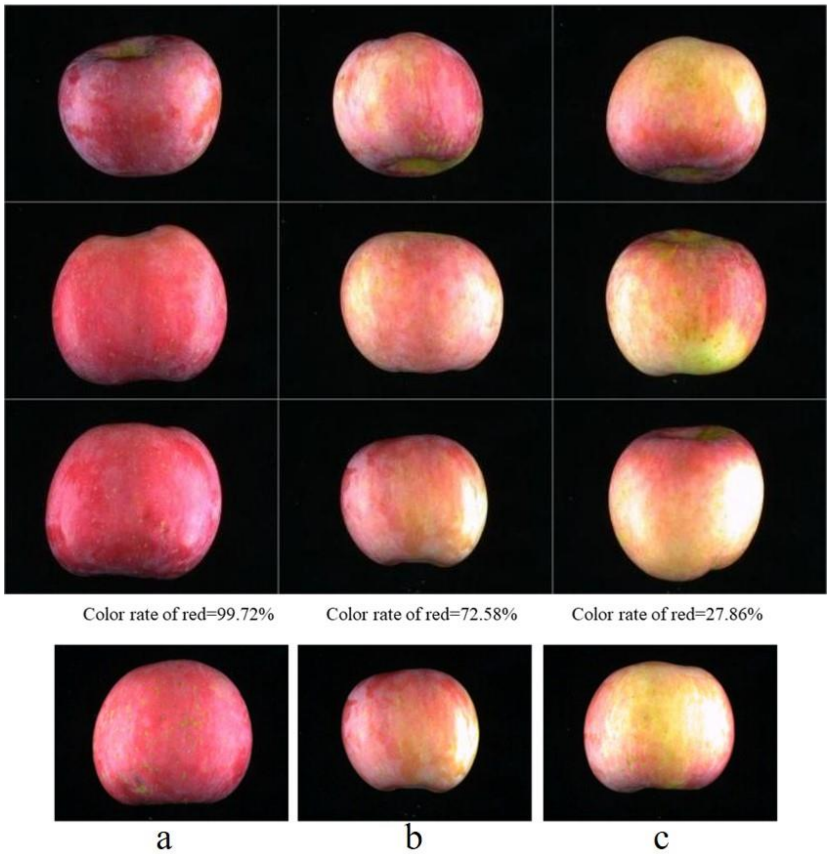


Fig.6 Comparison of apples with different colored areas

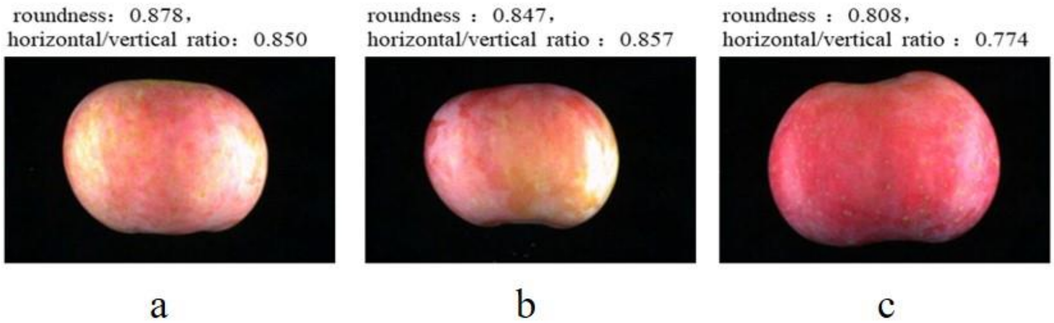


Fig.7 Comparison of roundness and transverse diameter/longitudinal diameter ratio of different apples

Defect detection results

In this paper, the stems/calyxes areas and defect areas of 100 defective apple samples were extracted and used for texture feature statistics. The results were shown in **Table.1**. Support vector machine(SVM) was selected for classification modeling in this study. By comparing the characteristic parameters of the stems/calyxes areas and defect areas, namely, angle second-order moment (ASM), contrast (CON), entropy (ENT) and inverse difference moment (IDM), it was found that contrast (CON)) would best reflect the difference in texture characteristics between the above two areas. Therefore, in order to accurately distinguish the stems/calyxes areas and defect areas, CON was used as texture feature variable and input into SVM for subsequent analysis and modeling after analyzing texture features.

One hundred samples were selected to extract the region of interest as training samples for subsequent modeling, and the remaining 100 apple samples were used to extract of the pedicel calyx region and the defect region for testing. From the test results of the model in **Table.2**, the overall accuracy rate of the model achieved 96.0%.

Table.1 Statistical results of texture characteristics of calyx parts and defects of fruit stalks

Sample classification	ASM				CON				ENT				IDM		
	max	min	mean		max	min	mean		max	min	mean		max	Min	mean
Stem/calyx	0.0837	0.0512	0.0684		1.533	0.286	0.286		3.678	2.549	3.079		0.836	0.636	0.761
Defect	0.0698	0.0326	0.0524		2.697	1.019	1.627		3.976	2.842	3.383		0.727	0.561	0.669

energy/angle second-order moment (ASM), contrast (CON), entropy (ENT), inverse difference moment (IDM).

Table.2 The test results of the model

defect/model category	Sample number	Determine the correct number	Accuracy/%
Stem/calyx—CON	100	99	99
Defect—CON	100	93	93
The total sample—ENT	200	192	96

V. Conclusion

(1) In this paper, a comprehensive detection and classification based on various appearance quality characteristics of apple was performed and the detection method for apple defect, size, fruit shape and color quality was constructed. In terms of defect detection, the classification of stems/calyxes areas and defect areas was realized, and the accuracy reached 96.0% by extracting texture features and establishing a support vector machine model. In terms of size detection, apple size was measured by calculating the maximum transverse diameter value on the surface of fruit diameter, and the classification accuracy was 92.6%. In terms of evaluation for fruit shape, the roundness and the aspect ratio were used to evaluate the fruit shape, and the results were consistent with the actual trend. Finally, the final fruit shape evaluation result was achieved by feature integration of the above two methods with pre-set weights. In terms of color evaluation, the red coloration was calculated through the H channel to reflect the color quality of apples.

(2) In this paper, an apple appearance quality detection system was designed. The detection standard setting function was added to the basic function of real-time display of the detection process and results. Single feature detection or comprehensive detection of four features could be realized as required. Simultaneously, the detection standard range under each feature quality could also be adjusted and set freely. What’s more, the system was more adaptive to user needs and the flexibility of the detection process was also greatly improved.

References

[1]. Da Silva, L.C., Et Al., Recent Advances And Trends In Extraction Techniques To Recover Polyphenols Compounds From Apple By-Products. Food Chemistry: X, 2021. 12: P. 100133.

[2]. Nandhini, P., J. Jaya, And J. George. Computer Vision System For Food Quality Evaluation — A Review. In Current Trends In Engineering And Technology (Icctet), 2013 International Conference On. 2013.

[3]. Aayush, K., Et Al., Innovations In The Development And Application Of Edible Coatings For Fresh And Minimally Processed Apple. Food Control, 2022: P. 109188.

[4]. Yossy, E.H., Et Al., Mango Fruit Sortation System Using Neural Network And Computer Vision. Procedia Computer Science, 2017. 116: P. 596-603.

[5]. Toylan, H. And H. Kuscu, A Real-Time Apple Grading System Using Multicolor Space. The Scientific World Journal, 2014. 2014.

[6]. Sofu, M.M., Et Al., Design Of An Automatic Apple Sorting System Using Machine Vision. Computers And Electronics In Agriculture, 2016. 127: P. 395-405.

[7]. Mendoza, F., P. Dejmek, And J.M. Aguilera, Calibrated Color Measurements Of Agricultural Foods Using Image Analysis. Postharvest Biology And Technology, 2006. 41(3): P. 285-295.

[8]. Surya Prabha, D. And J. Satheesh Kumar, Assessment Of Banana Fruit Maturity By Image Processing Technique. Journal Of Food Science And Technology, 2015. 52(3): P. 1316-1327.

[9]. Pereira, L.F.S., Et Al., Predicting The Ripening Of Papaya Fruit With Digital Imaging And Random Forests. Computers And Electronics In Agriculture, 2018. 145: P. 76-82.

[10]. Liming, X. And Z. Yanchao, Automated Strawberry Grading System Based On Image Processing. Computers And Electronics In Agriculture, 2010. 71: P. S32-S39.

[11]. Da Costa, A.Z., H.E. Figueroa, And J.A. Fracarolli, Computer Vision Based Detection Of External Defects On Tomatoes Using Deep Learning. Biosystems Engineering, 2020. 190: P. 131-144.

[12]. Mohana, S. And C. Prabhakar. Extraction Of Shape Features Using Multifractal Dimension For Recognition Of Stem-Calyx Of An Apple. In Proceedings Of The 3rd International Conference On Frontiers Of Intelligent Computing: Theory And Applications (Ficta) 2014. 2015. Springer.

[13]. Moallem, P., A. Serajoddin, And H. Pourghassem, Computer Vision-Based Apple Grading For Golden Delicious Apples Based On Surface Features. Information Processing In Agriculture, 2017. 4(1): P. 33-40.

[14]. Ropelewska, E., The Use Of Seed Texture Features For Discriminating Different Cultivars Of Stored Apples. Journal Of Stored Products Research, 2020. 88: P. 101668.

[15]. Cavallo, D.P., Et Al., Non-Destructive And Contactless Quality Evaluation Of Table Grapes By A Computer Vision System. Computers And Electronics In Agriculture, 2019. 156: P. 558-564.