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Full Length Research Paper

Detection of potato's size based on centroidal principal axis

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As the detection of the major and minor axes is an important indicator of potatoes grading, a fast, accurate and non-destructive method for sorting potatoes is in great demand. In this study, the technology of machine vision was employed to detect the major and minor axes of potatoes. A method to detect the size of potatoes is presented based on the centroidal principal axis of potatoes. Firstly, the color space of the image was converted from RGB to HSI, by applying the Otsu, a method of single threshold segmentation, to the H component values of the HSI image, binary image was gained through extracting potatoes from the gray images of H component values, which were preprocessed with the denoising method of a mean filter. Through filling and morphological erosion, the integrated potatoes image was obtained. Secondly, the potato image was rotated to a certain angle, which was calculated by the character of the principal moments of inertia of potato. The length and width of the external rectangle for potato in pixel-level are considered as the feature values of its major and minor axes. Thirdly, through regression analysis, the correlation coefficients of the major and minor axes are 0.9656 and 0.9166, respectively. For major axes, the maximal absolute error and relative error between the practical value and predicted value are 4.20 mm and 6.08%. For minor axes, the maximal absolute error and relative error are 3.18 mm and 7.42%. It requires only 1.38 s for processing a image by the centroidal principal axis, however, the time is 15.72 s for MER. Experimental results show that, with accurate and fast properties, the proposed potato's size detection method can provide a basis for on-line detection. Since the fact that the MER takes longer time to get the major and minor axes, in this study, the detection method based on the centroidal principal axis is introduced, which is accurate and fast. Besides, the method can be widely used in the dimension detection for other agricultural products.

Key words: Potatoes, machine vision, the major and minor axes, centroidal principal axis.

INTRODUCTION

Potatoes automatic classification technology is of prime importance to enhance the economic value of the potato. In recent years, with the development of machine vision technology, machine vision-based agricultural grading equipment has started commercial production in developed countries. Therefore, developing a rapid machine vision-based detection method will have great significance to the potato industry.

Machine vision (MV) is a technique, which uses machines instead of human eyes in carrying out measurement and judgment. The research and application of machine vision in agriculture began in the quality and classification of fruits and vegetables. late 1970s, mainly for non-destructive testing of the Marchant et al. (1988) developed High speed potato sorting system by using computer machine vision can sort 40 potatoes per minute by the size. Tao et al. (1995) introduced A Fourier-based shape separation method for shape grading of potatoes based on machine vision. Zheng et al. (2009) developed a MV-based automatic detecting and grading method of potatoes according to their size, shape and sprout, with a precision which was up to 88.0%

In the MV-based detection of the size of agricultural products, minimum enclosing rectangle (MER) is a commonly used method, which needs continuous rotation and is time-consuming. In this study, an accurate and fast detection method is presented based on the principal moments of inertia to detect the size of potatoes. We first converted the RGB image to HIS image and get the

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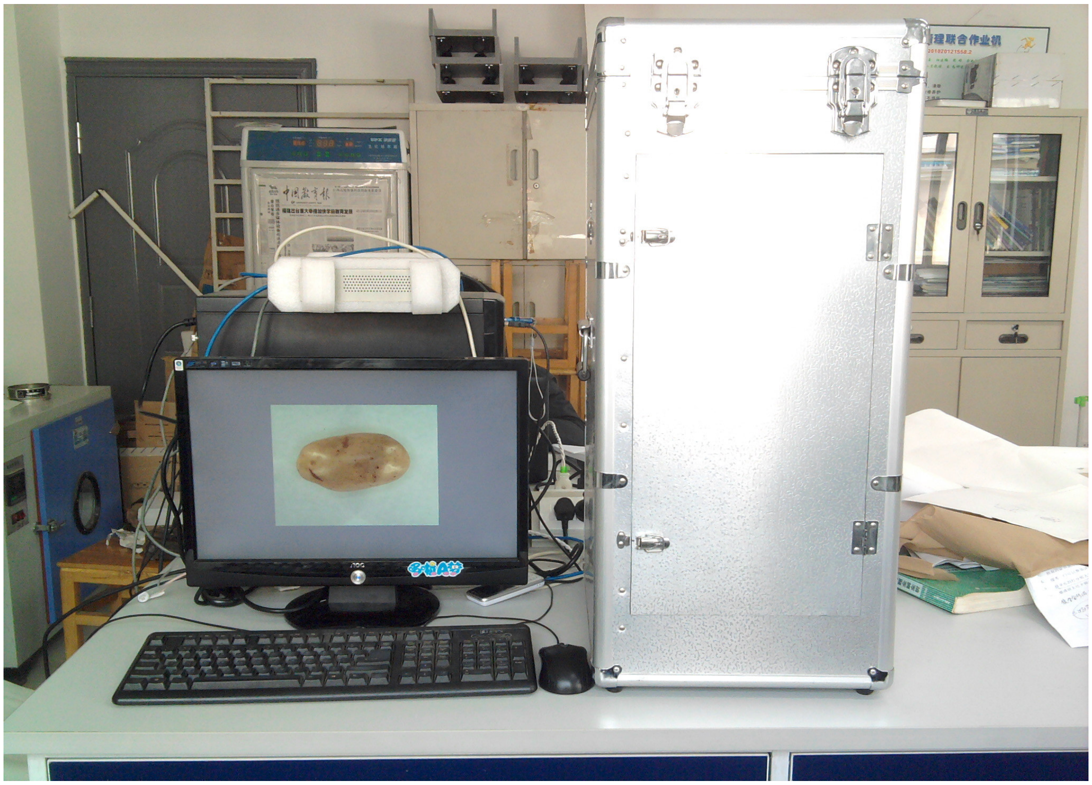


Figure 1. MV-based potatoes detection platform.

binary image by Otsu, then calculate the intersection angle between the principal axis and the horizontal axis by the centroidal principal axis, simultaneously, rotate the binary image with the intersection angle, finally processed by regression analysis.

MATERIALS AND EQUIPMENTS

MV-based potatoes detection platform

The platform in the experiment consists of an aluminum alloy box, the light source, CCD image sensor, image grabbing card and PC. The CCD image sensors include a scA1390-17fc-type camera by German company, Basler and the M1214-MP lens. The image grabbing card's model is Meteor2-1394. The light sources are a 32 W ring fluorescent and 4 32 W strip fluorescent. The background of the RGB image is white. Figure 1 shows the MV-based potatoes detection platform. When the system works, the AD converter converts the image signals acquired by the CCD image sensors to digital signals, which are sent to the PC by the image grabbing card for digital imaging processing.

The establishment of potato sample set and image sample set

The sample set in the experiment included 132 potatoes in Huangxin variety. Before they were stored, the samples were bagged after cleaning away the soil and being wiped by a dry dish cloth. The samples were labeled HM001–HM127. 732×578 RGB images were taken from the samples. Figure 2 shows the typical samples of potato RGB images.

IMAGE SEGMENTATION

There are two main segmentation methods based on machine vision. One is segmentation based on the gray image, and the other is segmentation based on color image.

Segmentation based on gray value

Digital image filtering

In order to smooth the image and reduce image noise, RGB image usually was processed by the image filters, such as average filter, median filter and Winer filter. In this study, the R, G and B components of the RGB image were respectively processed by median filter. Figure 3 shows the image of HM001 and the image after median filtering.

Gray image based segmentation

The RGB image was converted to a gray image, and the following conversion formula was used:

$$Gray = R \times 0.299 + G \times 0.587 + B \times 0.114$$

Where R, G and B indicate the corresponding color value of the red, green and blue components of the RGB image, respectively.

From the gray-level histogram, we know that the gray level range of the potato region is from 40 to 110, while the background gray range is from 110 to 175. Figure 4(a) shows the image and its gray-

Figure 2. The typical samples of potato RGB images.

level histogram of HM001 which was gained from the original RGB image. Figure 4(b) shows the image and its gray-level histogram of HM001 which was gained from the Filtered RGB image. The result shows that median filtering Not only reserved the trough between the two peaks in the original histogram and characteristics of potato (edges, texture and shape, etc.), but also made the image more smooth.

Then the binary image of HM001 was gained by Otsu. Figure 5 shows the binary image after processed by gray image based segmentation.

Because of the uneven surface of the potato and uneven distribution of light, the method is not significant. Figure 6 shows the histogram of HM010 after filtering, in which there is only one peak. The figure also shows the segmentation rustle of HM010, which illustrates that the effectiveness of segmentation method is inadequate.

Segmentation based on HIS

Color spaces conversion

The gray image based segmentation will lead to incomplete segmentation, which also result the losing of the edge. Thence, in this study, a segmentation method based on color image was presented. However, the RGB image is constituted by the three monochrome images(R, G and B), in which the color and grayscale can not be separated out. HSI color space, which is closer to human perception of color than RGB space, use hue (H), saturation (S) and intensity (I) to describe color body.

Formulation (1) was used to Extract H (hue) component from the RGB image:

$$H = \begin{cases} \theta & if \quad B \le G \\ 360 - \theta & if \quad B > G \end{cases} \qquad (1)$$

In which,

$$\theta = \arccos\left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2 + (R-B)(G-B)]^{1/2}} \right\}$$

Figure 7 shows the result of HM010 after processed by Color space conversion.

Background segmentation

After processing by average filtering (Figure 8), the binary image was extracted from the H component through Using Otsu. Finally, integrated potato binary image was acquired by filling and erosion, in which the pixel value of potato was 1 and the pixel value of the background was 0. Figure 9 shows the images processed by HSI color space segmentation method.

FEATURE EXTRACTION

Because of the direction of potato the image is neither vertical nor horizontal, we need to rotate the binary image with the intersection angle, which is between the principal axis and the horizontal axis. Usually, MER means rotate the image with a certain angle continuously, which is considered time-consuming. In this study the method based on the centroidal principal axis is presented.

Centroidal principal axis

The algorithm which can calculate the intersection angle between the principal axis and the horizontal axis is the following:

1. Calculate the coordinates of centroid by Formulation (2):

$$x_c = \frac{S_y}{A} \quad y_c = \frac{S_x}{A} \qquad (2)$$

2. Move the coordinate system until the origin of coincides with the centroid. The moments of inertia and product of inertia on the coordinate system can be calculated by Formulations (3), (4) and (5). In this study we suppose that the area of each pixel in the binary image is 1, in other words, $\mathrm{d}A = 1$.,So, Formulations (3), (4) and (5) were changed into Formulations (6), (7) and (8). Then I_x, I_y, I_{xy} are put into Formulation (9) to obtain the intersection angle between the principal axis and the horizontal axis:

$$I_x = \int_A y^2 \,\mathrm{d}A \qquad (3)$$

$$I_y = \int_A x^2 \,\mathrm{d}A \qquad (4)$$

$$I_{xy} = \int_A xy \,\mathrm{d}A \qquad (5)$$

$$I_x = \sum_{i=1}^{N} y^2 \qquad (6)$$

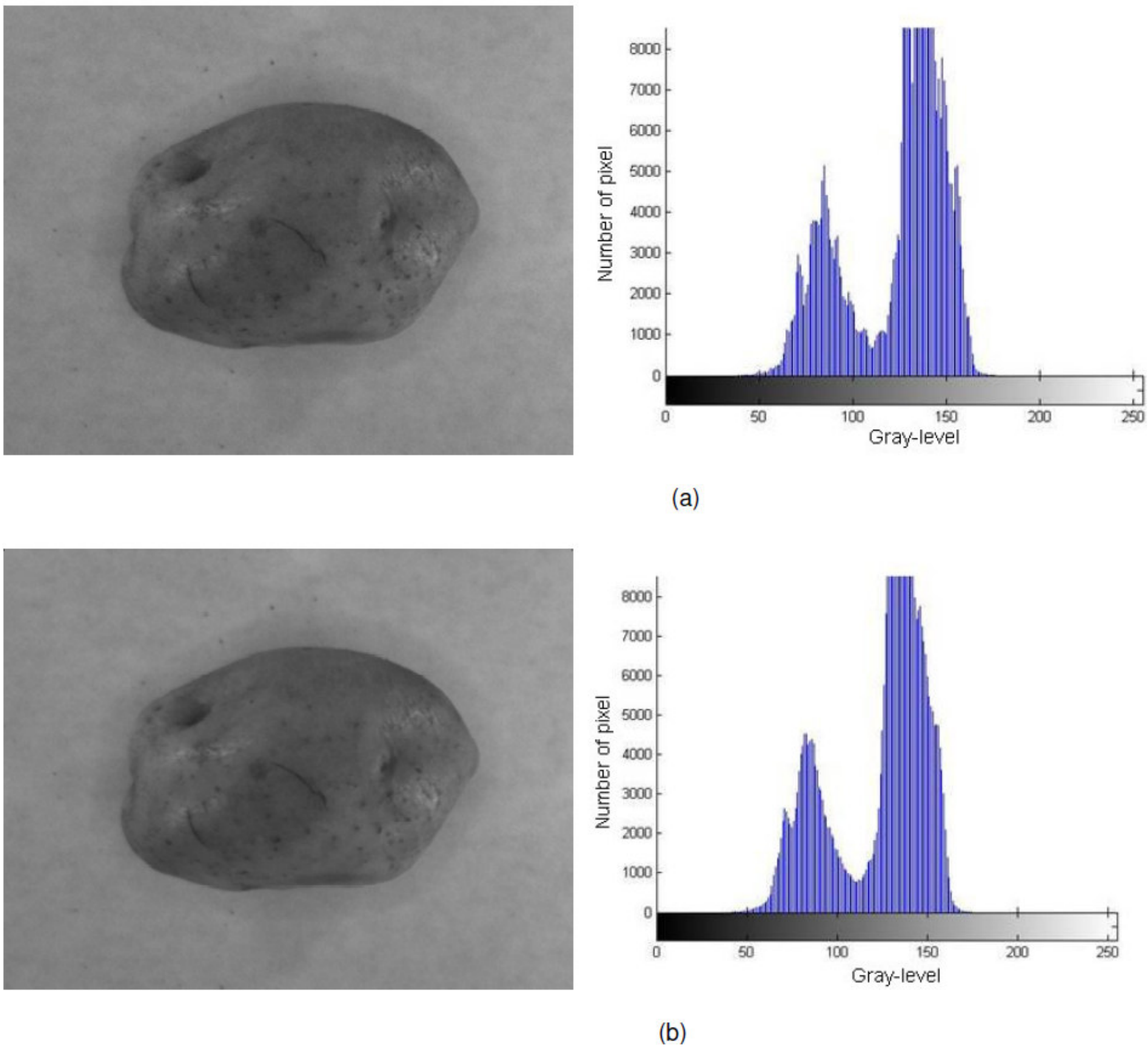


Figure 4. Gray image and gray-level histogram of HM001. (a) Gray image and gray-level histogram without filtering; (b) gray image and gray-level histogram after filtering.

$$I_y = \sum_{i=1}^{N} x^2 \qquad (7)$$

$$I_{xy} = \sum_{i=1}^{N} xy \qquad (8)$$

$$\alpha_0 = -\frac{1}{2}\arctan\frac{2I_{xy}}{I_x - I_y} \qquad (9)$$

3. After contrarotating the image with the intersection angle (α_0), at this time, the potato is horizontal and its external rectangle is the minimum enclosing rectangle (MER).

Figure 10 shows the image processed by the method based on centroidal principal axis.

Result shows that, in MATLAB, it requires only 1.38 s for processing a image by the centroidal principal axis, however, the time is 15.72 s for MER. We can figure out that the MER takes longer time to get the major and minor axes than centroidal principal axis.

Feature parameter extraction

The length and width value of the rectangle respectively were saved as the characteristic parameter of the major and minor axes.

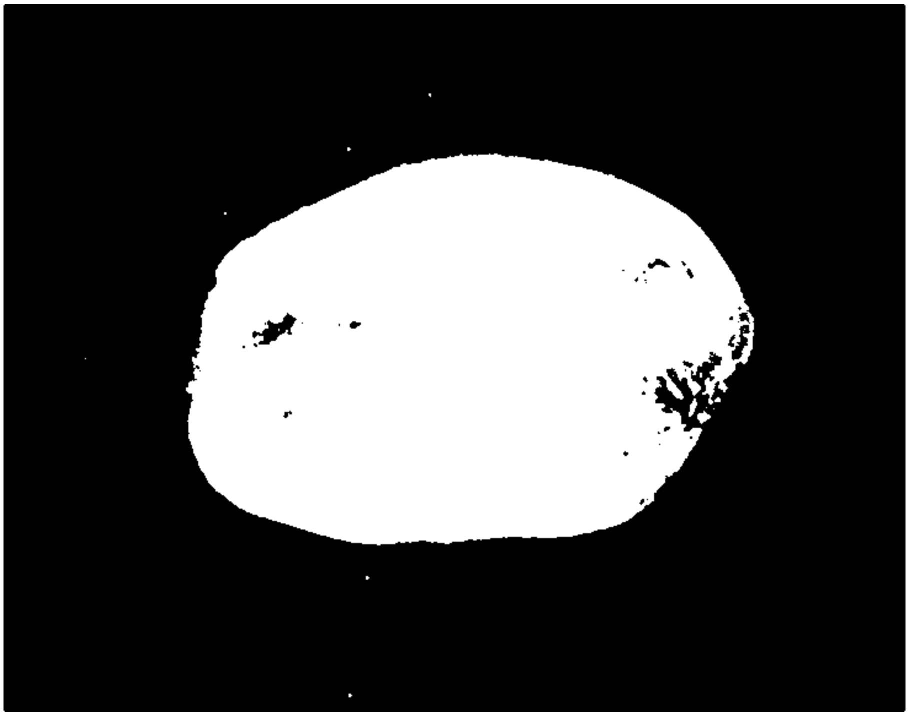
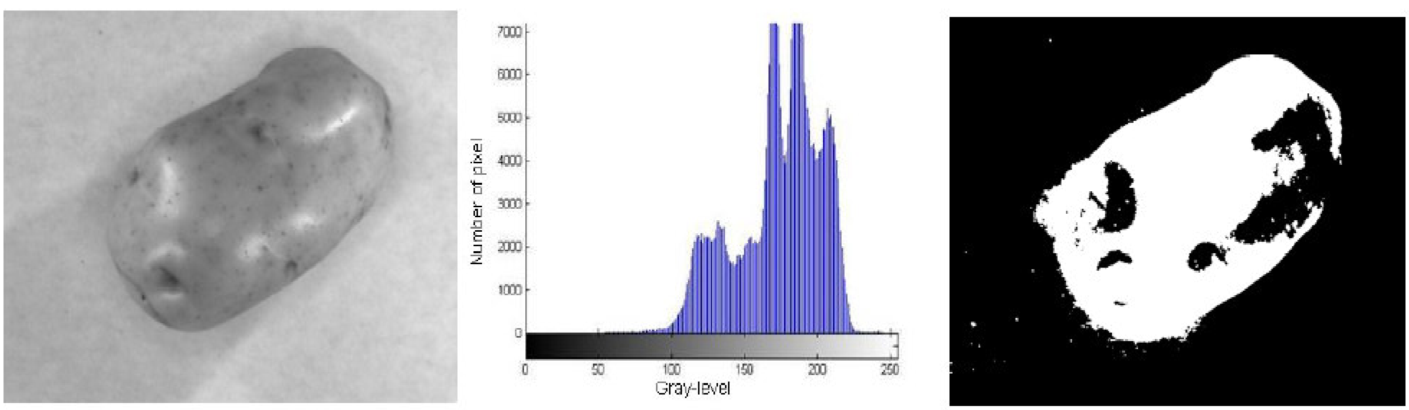


Figure 5. Binary image of HM001was gained by Otsu.

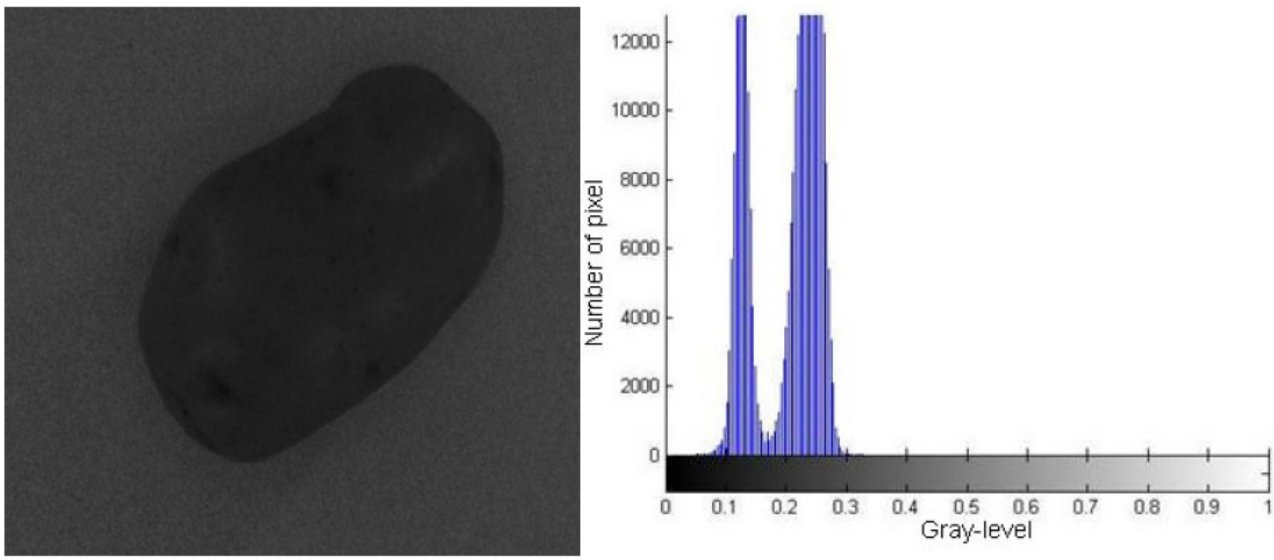


(a) (b) (c)

Figure 6. Gray image, gray-level histogram and binary image of HM010. (a) Gray image; (b) gray-level histogram; (c) binary image.

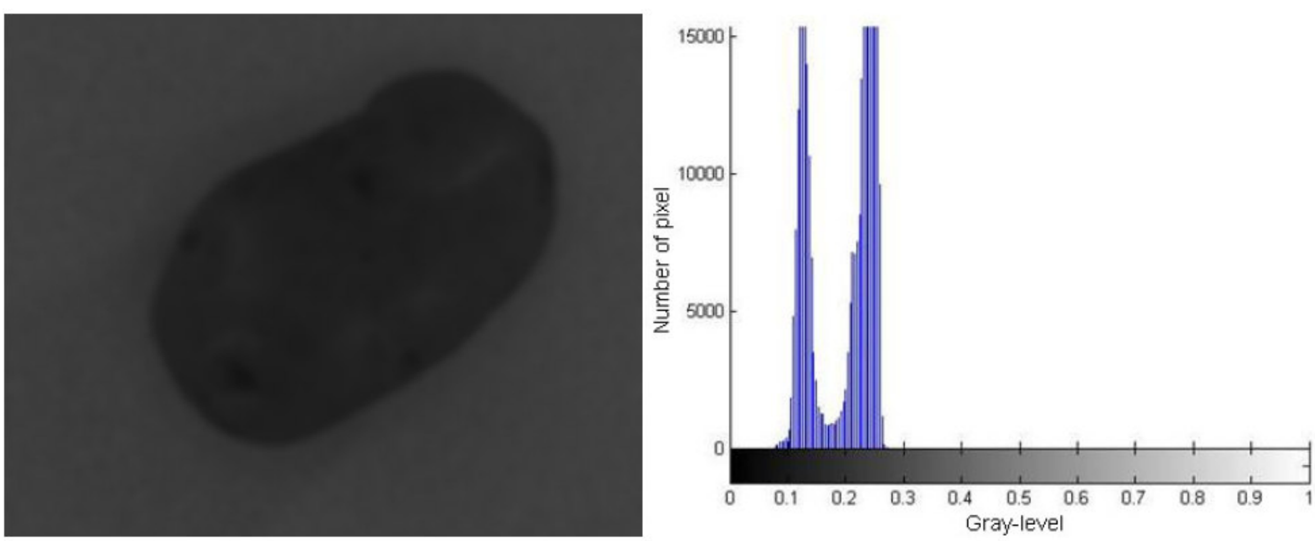
REGRESSION ANALYSIS

Regression models were established by the regression analysis between the major and minor axes and their parameter extraction. Respectively, the regression models of the major and minor axes were y = 0.1766x + 3.5463 and y = 0.1702x + 2.8544. The correlation coefficients of the major and minor axes are 0.9656 and 0.9166, respectively. For major axes, the maximal absolute error and relative error between the practical value and predicted value are 4.20 mm and 6.08%. For minor axes, the maximal absolute error and relative error are 3.18 mm and 7.42%. Figures 11 and 12 show the results of the regression analysis with centroidal principal axis. Nevertheless, from Figures 13 and 14, which show the results of the regression analysis with MER, we can learn that the model of centroidal principal axis is more accurate than MER.



(a) (b)

Figure 7. The result of HM010 after processed by color space conversion. (a) H (hue) component image; (b) histogram.



(a) (b)

Figure 8. H (hue) component image and histogram of HM010 after processed by average filtering. (a) H (hue) component image after filtering; (b) histogram.

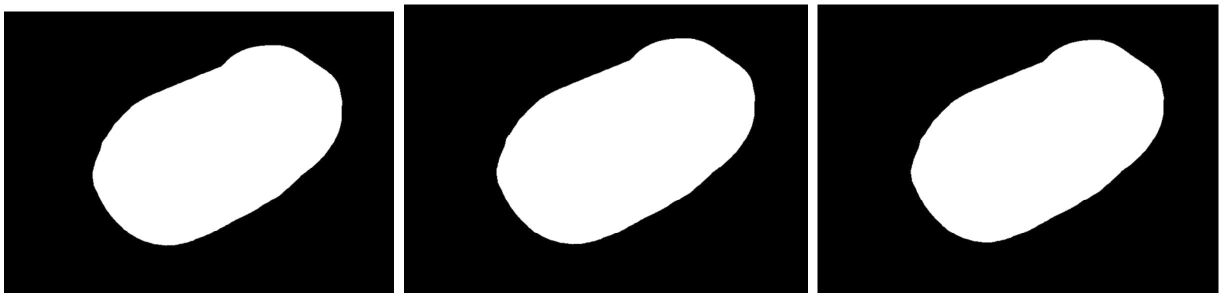
Conclusions

Table 1 shows that, with accurate and fast properties, the proposed potato's size detection method based on centroidal principal axis (CPA) can provide a basis for on-line detection. The following conclusions were reached:

1. The feature extraction method based on the centroidal principal axis in this study was verified that it is faster and with smaller computational than MER.
2. Because of the uneven surface of the potato and uneven distribution of light, segmentation based on gray

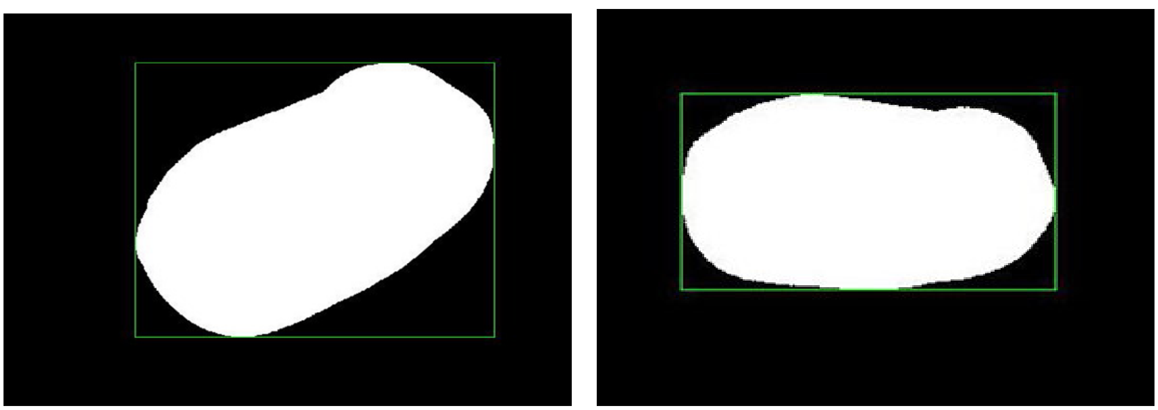
image is not significant. This study chooses the HSI color space to extract the binary image of potato, which proved effective.

3. The results of the regression analysis show that the



(a) (b) (c)

Figure 9. Images processed by HSI color space segmentation method. (a) Binary image by Otsu; (b) image after filling; (c) image after erosion.



(a) (b)

Figure 10. The image processed by the method based on centroidal principal axis. (a) Original binary image; (b) image after contrarotating.

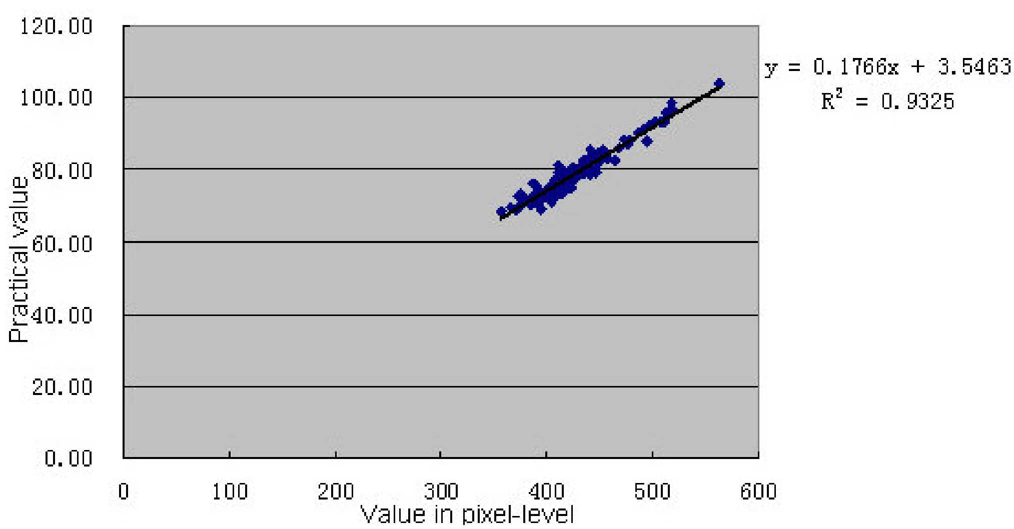


Figure11. The result of the regression analysis for the major axes with centroidal principal axis.

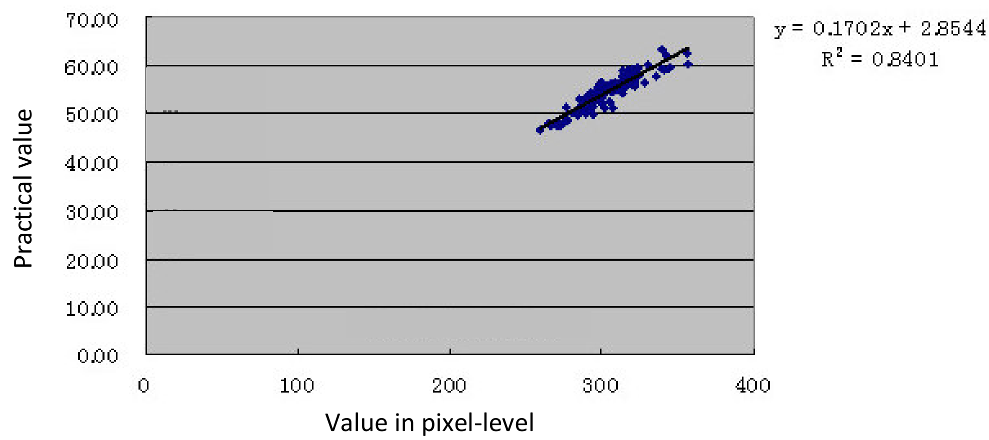


Figure 12. The result of the regression analysis for the minor axes with centroidal principal axis.

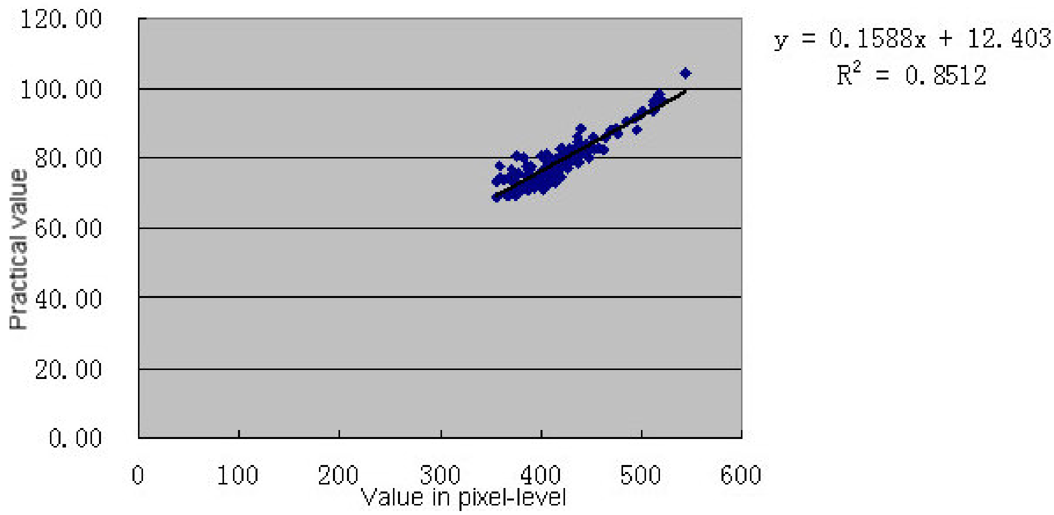


Figure 13. The result of the regression analysis for the major axes with MER.

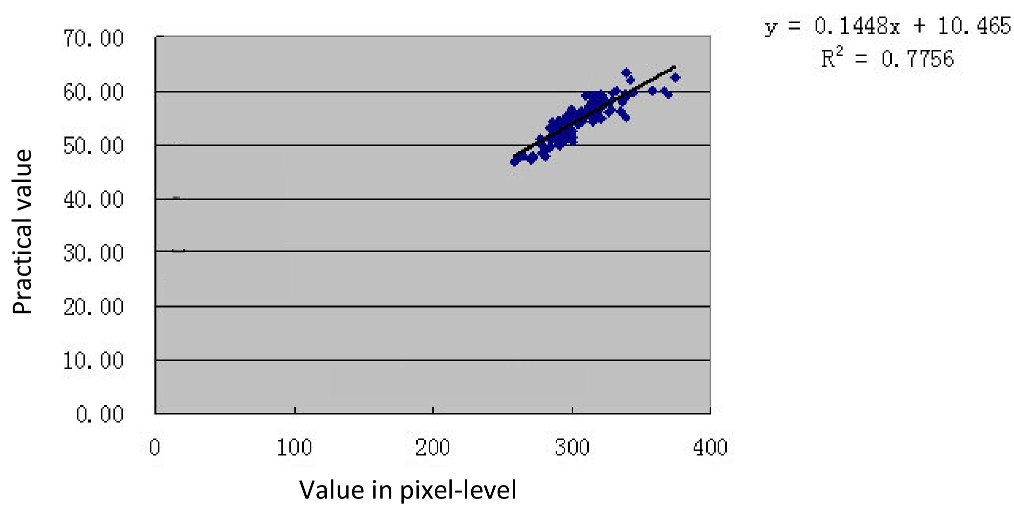


Figure 14. The result of the regression analysis for the minor axes with MER.

Table 1. Comparison of two methods results.

Method	Time (s)	Correlation coefficients		Maximal absolute error		Maximal relative error	
		Major axes	Minor axes	Major axes	Minor axes	Major axes (%)	Minor axes (%)
CPA	1.38	0.9656	0.9166	4.20 mm	3.18 mm	6.08	7.42
MER	15.72	0.9226	0.8807	8.39	4.50	10.42	8.10

regression models were accurate, which is due to the accurate detection method based on the centroidal principal axis.

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