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Detection and research of pest insect to fresh jujubes based on X-ray

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ABSTRACT

Pest insect in fresh jujubes seriously affects the eating. For the sake of gaining comprehensive situation of inside pest insect, research is conducted based on X-ray. Firstly, collect X-ray patterns of 150 normal and pest-insect Huping jujube samples respectively; secondly, preprocess them with 3*3gaussian filter method; thirdly, draw the pest-insect characteristics adopting methods of image enhancement, image segmentation and morphological processing; fourth, construct image evaluation criterion of Pixel ratio, and divide the 150 normal Huping jujubes and 150 pest-insect ones randomly into calibration set and prediction set with the proportion of 4:1; and lastly, as for calibration set, take the total highest accuracy as the criterion to determine the optimal threshold value, which is 3.75%. And take this value as criterion to discriminate the 60 samples in prediction set, and the accuracy is 86.7%. It proves that the detection and research on pest insect of fresh jujubes based on X-ray are effective, which provide foundation to perfect the on-line nondestructive testing technology and methods of pest-insect fresh jujubes.

KEYWORDS

X-ray; Fresh jujube; Pests insect; Detection; Image Processing.

INTRODUCTION

Jujube planting suffers easily pest insect, with worm stings 1.00mm-2.50mm [1] micro-hole diameter of on the surface of jujube. While the worm stings are invisible and difficult to sort by human identification.

The powerful penetration of X-ray has direct access to the interior quality characteristics of substance and distinctive advantages in agricultural detection. N.Kotwaliwal.etc. [2] have detected the thickness of stone and flesh of walnuts using X-ray and gotten that the detection misjudgment rate of edible walnuts is less than 10 percent. Toyofuku N. etc. [3] have had a non-destructive testing of the special organization of fruits based on X-ray. Els Herremans etc. [4-5] have had a classification detection of water core apples and intact apples based on X-ray and nuclear magnetic resonance. For classification of employing the image processing based on threshold segmentation, the classification accuracy of image reaches 89 percent based on X-ray while 79 percent based on nuclear magnetic resonance. Hong Guan [6] has adapted OTSU in X-ray image segmentation and gotten a good result. Kang Likui etc. [7] have taken apples as objective and found image enhancement method of wavelet transform achieve a better effect than that of histogram equipoise and local contrast. Sun Teng[8] has employed X-ray to predict the internal quality model of apples and found that partial least- squares regression achieve a better effect. Lv Song etc. [9]have used X-ray in the net content detection research of BQF shrimps and proved that the correlation is above coefficient R 0.94 and the relative error is below 15 percent.

This paper conducts a discrimination of intact jujubes and jujubes with insect attack by employing X-ray imaging technique to get jujube images, making image processing using image denoising, image enhancement, image segmentation and morphologic processing, constructing pixel aspect Ratio as evaluating index, and defining threshold value of jujubes with insect attack.

EXPERIMENT MATERIALS AND EQUIPMENTS

Experiment materials

This research took the achievement of classification discrimination between intact jujubes and jujubes with insect attack as the goal and the Huping jujubes in Taigu County as objective. The needed Huping jujubes (150 intact jujubes and 150 jujubes with insect attack) were picked up in the same orchard in the western suburb of Taigu County.

Experiment equipments

This experiment employed X-ray machine made in Shanghai New Real Estate Medical Equipment Company to pick up X-ray images of Huping Jujubes (Figure 1). This X-ray machine mainly included high-volt generator, X-ray source assembly, diagnostic couch, and chest radiography, IBMPC machine with high configuration, digital image system, camera, printer, and supporting software systems. The experimental conditions were: the frequency of high-volt generator was 100Hz, the maximum power was 50kW, the voltage and tube current were 48kV and 1.3mA respectively and the scale of digital image system was 1024×1024×10.

Figure 1: View X-ray machine

Collection of experimental data

Label these 300 intact and insect-attack jujubes respectively, put them flatly on the experimental table along the long axis of the jujube pits, and collect the X-ray images. The obtained original image of jujube samples was shown in Figure2, with the size of 1024×1024.

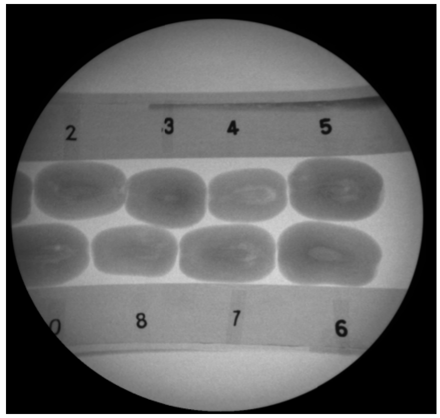


Figure 2: Original images

After image collection, use vernier caliper to measure long diameter and short diameter and record them; cut the jujube at the worm wholes and along the long axis and record whether it is insect-attack jujubes or jujubes with frass and whether the worm hole is vertical or not; put the jujubes and the X-ray images together; use vernier caliper to measure the width (long axis) and height (short axis) of verminous part and make a record.

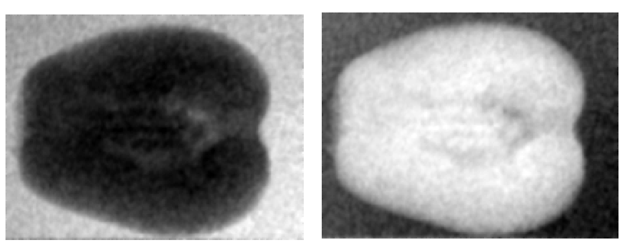
EXPERMENTAL RESULTS AND ANALYSIS

Image preprocessing

The fuzziness of the original images was visible by eye because of the noise, whose grey discontinuous on the frequency domain showed high frequency properties [10]. The improvement of image quality needed denoising preprocessing. Cut the original image gotten by X-ray into single ones artificially, and use 15 ways of denoising preprocessing: 3×3 median filter,5×5 median filter,7×7 median filter,3×3 mean filter,5×5 mean filter,、7×7 mean filter,3×3wiener filter, 5×5wiener filter,7×7wiener filter, 3×3 gaussian filter, 7×7 gaussian filter, 11×11 gaussian filter, Butterworth LPF, wavelet global threshold denosing[11], and wavelet packet global threshold denosing[12]. Evaluate them with Means square error (MSE), Peak signal-to-noise ratio (PSNR) and Mean absolute error (MAE). The analysis showed the best preprocessing effect of 3×3 gaussian filter for its EMS value and MAE value are the minimum, and its PSNR value was the maximum. Therefore, image follow-up processing would base on this way.

mage enhancement

Gray scale linear transformation was used to extend the gray value of flittered image to [0 255] for contrast enhancement. We got the enhanced image highlighting verminous part and negative image shown in figure 3(a) and 3(b).



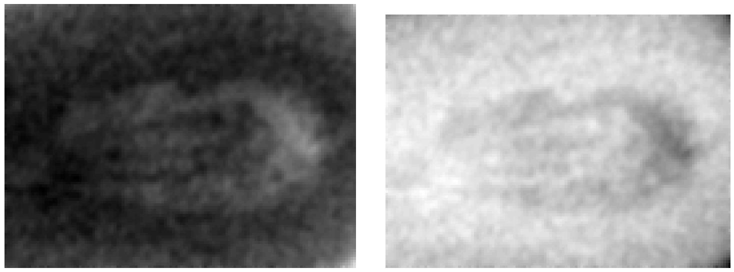
(a) (b)

Figure 3: Images of after image enhancement

Image segmentation method

Verminous part of jujubes mainly was around the center of kernel as Insects went into fruitlet [13], and absorb nutrition around the kernel to erode the internal organization of jujubes until maturity, which resulted in inedibility of these jujubes. Therefore, Matlab programming platform was used to search for the center of inertia of jujubes and establish an automatic identification template based on its distinctive characteristics. Through statistics of height (short diameter) and width (long diameter) insect-attack jujubes and statistics of height (short diameter) and width (long diameter) of the distance between verminous part and the kernel centered the jujube center of inertia, we found that the automatic identification template is [L/2 B/2] , during which, the height and width of insect-attack were L mm and B mm respectively.

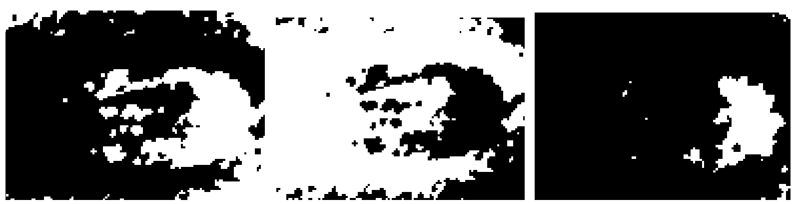
Supposed that the height of pixel of original image was R' and its width is C', while the height and width of pixel of cut-out rectangular center were R and C, R×C is approximately equal to (R'/2) ×(C'/2). The image from this template is seen in figure 4, in which (a) is the image cut out from the verminous part, (b) is the negative image of verminous part.



(a) (b)

Figure 4: Centre images of pests

One important features of X-ray image was the grey value was relevant to the thickness and intensity of the samples [14]. Differences in the individual features such as pest situation, place, intensity, experimental plat and space leaded to differences in the pest segmentation threshold. With iterative operation, adaptive threshold of each insect-attack jujube was available. While for intact jujubes, the adaptive threshold was that between the stone and flesh. Therefore, to separate the verminous part and integrate stone and flesh of intact jujubes in the same grey value, iterative operation was used to get the optimum segmentation threshold. The statistics showed that the threshold value of the verminous part mainly centralized in the range of 52-71, and the optimum is 61.5, and the corresponding threshold value image was acquired (seen 5a). Method of maximum classes square error [15] was used to calculate the adaptive threshold thus to acquire the binarization image of the negative image in pest center (seen figure 5b). Subtraction between the threshold image and negative binarization image could get the image after preliminary segmentation (figure 5c).



(a) (b) (c)

Figure 5: Images of segmentation

Morphological processing

In the segmented images of jujube verminous part, some dispersed and tiny normal part would be misunderstood as verminous part. In order to reduce the segmentation error and extract corresponding shape, we used morphological processing to make a further process by adopting 6×6 erosion, 3×3 inflation, logic and calculating and hole filing operation, only to find this way was available, seen Figure 6(a) (b) (c) (d).

(a) (b) (c) (d) (e)

Figure 6: Contrast Images of pest jujube through morphological processing

Detection and analysis of pest jujubes

Identification of evaluation index

According to the size of jujubes, we used automatically identified rectangular template to segment their center domains, and then statistic the number of pixel whose grey value was 1, and identity threshold [16] and took it as the evaluation. But in real practice, it was difficult to distinguish pest jujubes from intact ones through direct statistics of the number of pixel, for jujubes were in different sizes and jujube center domains segmented by automatically identified rectangular template are different. Therefore, this paper took a detection using the percentage of the number of pixel whose grey value was 1 accounting for the total number as the evaluation index and defined it as pixel ratio denoted by K, and its expression was seen in Formula 1.

$$K = \frac{M}{R \times C} \times 100\%$$ （Formula1）

Where, M—the number of pixels whose grey value is 1(shown in white)in the segmented image of jujube center domains after morphological processing; R—height of segmented image of center domain; C—width of segmented image of center domain.

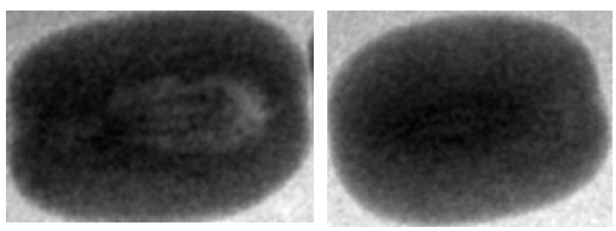
Results and analysis

In this experiment, 300 samples were divided into a calibration set of 240 and a predication set of 60, in which, the calibration set consists of 120 intact ones and 120 pest ones, and the predication set includes 30 normal ones and 30 pest ones. The calibration set was made a image processing using the way in 2.1 and 2.2, thus to get the image processed by the morphological processing. Matlab programming platform was used for pest determination, during which, threshold value was defined by the pixel ratio extracted from the calibration set. The analysis showed that if the pixel ratio is less than the threshold value, the jujube is normal, or it is insect-attack. In this experiment, we made a statistics of pixel ratio for the calibration set, and take the highest determination accuracy as the final threshold value for determination classification. According to the statistics, 3.75% was chosen as the final pixel ratio to establish determination modes, and the results were shown in Table 1, where, the total misjudgment ratio was 12.9%, and the accuracy is 87.1%.

TABLE 1: Statistical results of Pixel ratio about pest's jujube and normal jujube

	Normal Jujubes	Pest Jujubes	Calibration Set
Sample number	120	120	240
Number for accurate determination	103	106	209
accuracy	85.8%	88.3%	87.1%
Number for misjudgment	17	14	31
Misjudgment ratio	14.2%	11.7%	12.9%

Through analysis of the calibration set, the predication set was verified and analyzed in the same way. The determination results from Matlab platform was shown in Figure 7.



(a) pest-insect jujube (b) normal jujube

Figure 7: Identifying's images of the output about jujube

TABLE 2: Statistical results of Pixel ratio about pest's jujube and normal jujube

	Normal jujubes	Pest jujubes	Predication set
Sample number	30	30	60
Number for accurate determination	25	27	52
accuracy	83.3%	90.0%	86.7%
Number for misjudgment	5	3	8
Misjudgment ratio	16.7%	10.0%	13.3%

Through statistics and analysis of the output image, the determination results of the predication set were shown in Table 2. It showed that, in this determination, the number for accurate determination was 52, while misjudgment was 8, and the accuracy reached 86.7%. The predicative result was more ideal.

DISUSSION

X-ray has powerful penetrability to substance, and its capacity is affected by the intensity of substance. The analysis of penetrability will explore the internal material. Therefore, X-ray imaging technology has a unique advantage in internal quality detection of products. Research in This paper shows that X-ray image is available to the nondestructive detection of pest jujubes, especially to those with frass around. It achieves the best effect with 100% accuracy.

Complexity in the internal pest jujubes may affect the accuracy of X-ray non-destructive detection such as the size and place of jujubes. Hence, grading is necessary before X-ray image collection. The putting place before X-ray image collection will affect the detection of pest jujubes of worm wholes without frass. When irradiation along the axis of the hole depth, only to get a spot. When irradiation along the angle formed with the axis of the hole depth, the oblique line on the X-ray image shows that this jujube is normal.

So far, there have been no standards for product detection with X-ray. Therefore, it is very important to choose proper detection parameters according to the characteristics of objectives. This study identifies the experimental conditions for the X-ray image collection through various choices and analysis: the frequency of high volt generator is 100Hz, the maximum power is 50kW, the volt and tube current is 1.3mA, and the digital image system is 1024×1024×10.

CONCLUSION

This paper made a preprocessing with 3×3 gaussian filter, and an image enhancement by extending the grey value of flittered image to [0 255] using grey linear transformation, took the center of enhanced image as the center to establish an automatic identification template [L/2 B/2]. This template was used for acquirement of the center of the pest jujubes. The optimum segmentation value acquiring by the iterative operation is 61.5, and correspondingly, we get the threshold value of the center domain of the pest part. Method of maximum classes square error is used to calculate the adaptive threshold thus to acquire the binarization image of the negative image in pest center. Subtraction between the threshold image and negative binarization image can get the image after preliminary segmentation. The pest feature region of Huping jujubes can be acquired with morphological processing adopting 6×6 erosion, 3×3 inflation, logic and calculating and hole filing operation. Take the pixel ratio as the criterion, and use it for determination of the threshold value of image with morphology processing. It shows that the optical threshold value is 3.75%. And take this value as criterion to discriminate the 60 samples in prediction set, and the accuracy is 86.7%. Therefore, this method is available to detection of pest jujubes. While given many factors affecting the X-ray detection effects, it needs further study to find method for experimental design, the optimum adaptive threshold value for image segmentation and determination of the evaluation indices.

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