Journal of Zhejiang University SCIENCE
ISSN 1009-3095
http://www.zju.edu.cn/jzus
E-mail: jzus@zju.edu.cn

Machine vision inspection of rice seed based on Hough transform*

CHENG Fang (成 芳)†, YING Yi-bin (应义斌)

(*College of Biosystems Engineering and Food Science, Zhejiang University, Hangzhou 310029, China*)

†E-mail: fcheng@zju.edu.cn

Received Oct. 28, 2003; revision accepted Dec. 3, 2003

Abstract: A machine vision system was developed to inspect the quality of rice seeds. Five varieties of *Jinyou*402, *Shanyou*10, *Zhongyou*207, *Jiayou* and II*you* were evaluated. The images of both sides of rice seed with black background and white background were acquired with the image processing system for identifying external features of rice seeds. Five image sets consisting of 600 original images each were obtained. Then a digital image processing algorithm based on Hough transform was developed to inspect the rice seeds with incompletely closed glumes. The algorithm was implemented with all image sets using a Matlab 6.5 procedure. The results showed that the algorithm achieved an average accuracy of 96% for normal seeds, 92% for seeds with fine fissure and 87% for seeds with incompletely closed glumes. The algorithm was proved to be applicable to different seed varieties and insensitive to the color of the background.

Key words: Hough transform, Incompletely closed glumes, Rice seed, Machine vision
Document code: A **CLC number:** TP39

INTRODUCTION

It is a common phenomenon that glumes of rice seeds are incompletely closed, especially for hybrid rice. The average proportion of hybrid rice seed with incompletely closed glumes is about 26% in nature. The threshing and drying in post-harvest handling will further increase the proportion. The germen segmentation is inhibited by ultraviolet illumination from sunshine while the germen epidermis cell stops growing because of shortage of water due to the limited moisture. These prevent the pericarp in rice from extending sufficiently. So the water satiety degree of rice seeds with incompletely closed glumes is lower than that of normal rice seeds. Sometimes rice seeds with incompletely closed glumes are deformed. During storage, rice seeds with incompletely closed glumes are susceptible to disease and attacks by bugs, which adversely affect the durability of normal rice seeds. Normal seed vigor declines slowly with the protection of well closed glumes; while the vigor of the rice seeds with incompletely closed glumes declines rapidly. Rice seeds with incompletely closed glumes lead to poor seed quality and are not desirable to producers.

Machine vision is a useful tool for external feature measurement. Automatic seed inspection using machine vision can improve the quality of the packed product, replace faulty manual evaluation, and reduce dependency on manpower. Machine vision techniques have been applied throughout the agricultural and food processing industry to inspect and sort biological materials. Machine vision provides a reliable and objective means for evaluating products based on visual features. The seed industry in particular has extensively utilized machine vision techniques for quality inspection. Examples

*Project supported by the National Natural Science Foundation of China (No. 60008001) and the Natural Science Foundation of Zhejiang Province (No. 300297), China

include inspection of corn kernel (Ng *et al*., 1998; Liao *et al*., 1993; Zayas *et al*., 1990), wheat classification (Zayas *et al*., 1985; 1996; Neuman *et al*., 1987), inspection of soybean seeds (Casady *et al*., 1992; Gunsekaran *et al*., 1988a; 1988b) and cereal grain classification (Satake *et al*., 1992; Sapirstein *et al*., 1987; Lai *et al*., 1986).

A new non-destructive machine vision method was developed to sort out rice seeds with incompletely closed glumes from normal rice seeds. The new method would enable rice seed producers to classify rice seed as normal seed, fine fissure seed and unclosed seed. Fine fissure seed is rice seed with tiny incompletely closed glumes which show to the naked eyes a white line between glumes although the tips of the glumes are closed. Fine fissure seeds could then be stored under strictly controlled condition separately from the normal seeds and inspected again before use. Unclosed seed is rice seed with obviously unclosed glumes which could then be stored separately for a relatively short time in dry condition and treated with antisepsis before use in some special fields as the seed quality is relatively low.

This paper aims at providing a sensitive scientific method for accurate inspection of rice seeds with incompletely closed glumes based on machine vision.

MATERIAL AND METHODES

System description

An imaging system was developed to identify external features of rice seed. The system consisted of a Matrox Meteor II PCI frame grabber used in a Pentium 4 computer. The frame grabber was connected to a Pulnix TMC7DSP CCD camera. The camera was connected via C-mount to an ANB847 50 mm lens with an ANB848 20 mm extension tube. The lens was surrounded with a 56 mm fiber optic ring lamp connected to a 12 V 100 W cold light source via an R-Φ8×1000 light beam. The camera was movable up and down through a sliding guide. After tests for increasing pixel resolution, the camera lens was mounted at a fixed distance of 130 mm from the surface of the sample table. To reduce the amount of ambient lighting, a black light chamber was constructed with camera lens and ring light mounted inside.

Matrox Intellicam Windows-based imaging software was used to acquire images from the frame grabber. This system produced clear 640×480, 8-bit images without shadow throughout 360°.

Samples and experimental procedure

Five varieties of *Jinyou*402, *Shanyou*10, *Zhongyou*207, *Jiayou* and II*you* rice seeds were used in this study. Samples of 100 normal seeds, 100 fine fissure seeds and 100 unclosed seeds were hand picked and visually separated into the three categories. Half samples of each category were laid on the sample table with white background and the other half on the sample table with black background. Images of each sample's one surface marked as "A surface" and the other reverse surface marked as "B surface" were taken using the system. Finally five image sets consisting of 3×2×100 original images each were established. To ensure system repeatability, a thin semitransparent plastic reference material was used to check the intensity of the light source periodically throughout the experiment.

Image pre-processing

Matlab 6.5 was used to implement the image processing algorithms. At first, an RGB image was converted to grayscale by means of converting the RGB values to NTSC coordinates, setting the hue and saturation components to zero, and then converting back to RGB color space. Then the image was converted into a binary image, based on global image threshold which was computed using Otsu's method. So the background which was white or black originally was eliminated. Connected components in the binary image were labeled to find the rice seed region of interest. The binary image and the grayscale image were both rotated an angle the same as that between the x-axis and the major axis of the ellipse that has the same second-moments as the selected region. The product of element-by-element multiplication (.×) of each corresponding pixel in the two images was inputted to an output image. The output image is shown in grayscale in the seed region whose major axis is parallel to the x-axis while the pixels value of the background was zero. At last, the Sobel method was used to find the edges of the output image.

Hough transform

Hough transform is the projection of the image intensity along a radial line oriented at a specified angle. The radon transform represents an image as a collection of projections along various directions. It is used in areas ranging from seismology to computer vision. A projection of a two-dimensional function $f(x, y)$ is a line integral in a certain direction. For example, the line integral of $f(x, y)$ in the vertical direction is the projection of $f(x, y)$ onto the x-axis; the line integral in the horizontal direction is the projection of $f(x, y)$ onto the y-axis. Projections can be computed along any angle. In general, the Hough transform of $f(x, y)$ is the line integral of f parallel to the y' axis.

$$R_\theta(x')=\int_{-\infty}^{\infty} f(x'\cos\theta-y'\sin\theta,\ x'\sin\theta+y'\cos\theta)\mathrm{d}y'$$

where $\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$

In this study, the angle theta degrees were 80° to 100° because the region of interest in the image was almost parallel to the x-axis after image pre-processing.

All 5×600 images in sample sets were pre-processed and Hough transformed. The typical original images of normal seed, fine fissure seed and unclosed seed of *Jinyou*402 are shown in Fig.1. The corresponding Hough transform results are shown in Fig.2 to Fig.4 respectively. The effects of Hough transform after pre-processing the three category images of the other varieties such as *Shanyou*10, *Zhongyou*207, *Jiayou* and II*you* are similar to *Jinyou*402.

Fig.1 Typical original images of normal seed, fine fissure seed and unclosed seed

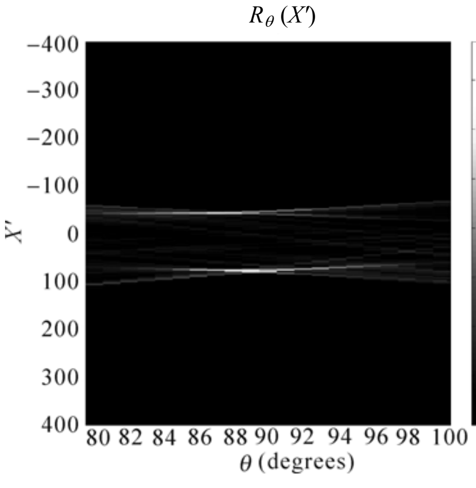

Fig.2 Result of Hough transform of normal seed image after pre-processing

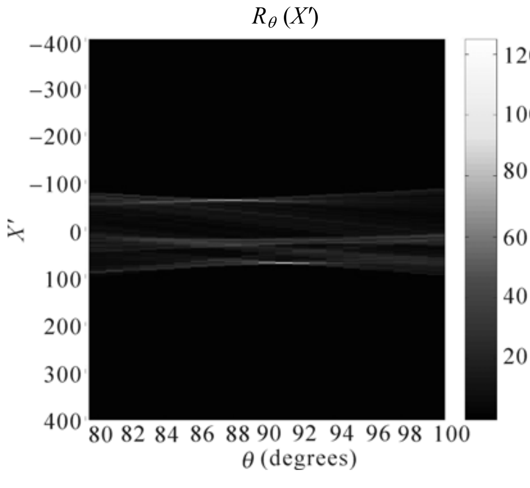

Fig.3 Result of Hough transform of fine fissure seed image after pre-processing

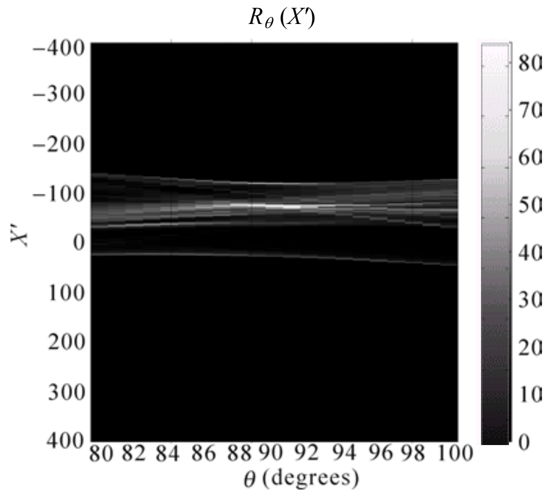

Fig.4 Result of Hough transform of unclosed seed image after pre-processing

Post-processing

The above typical Hough transform results of the three categories were compared at first. The locations of strong peaks in the Hough transform matrix corresponded to the location of straight lines in the original image. Because the lines of interest in the image were mostly in the middle of the seed region and almost horizontal after image preprocessing, we found that more obvious fissure between seed glumes in the original image, led to more bright lines in the middle of x' direction and θ=85°–95° in the Hough transform result image. The strong peaks with R value exceeding the half maximum value of $R_\theta(x')$ remained while the other R values were changed to zero by post-processing program. The undesired valley information was eliminated by the post-processing method.

Feature extracting and object recognition

A simple threshold method was used for feature extraction and object recognition. The R value scale of the post-processing result was found at first. Then all R values were identified to include those whose absolute differences from the maximum or minimum were less than a specified threshold as a group. The number of groups in the post-processing result was extracted as image feature. A sample was recognized as a normal seed when the post-processing result of the sample image could be described as 2 groups. When the post-processing result of a sample image was described as 3 groups or more than 3 groups, the sample could be recognized as a fine fissure seed or an unclosed seed respectively.

RESULTS AND DISCUSSIONS

Estimation result

All 5×600 original image samples were used to test the algorithm based on Hough transform. The statistical results indicated that the algorithm achieved average recognition accuracy of 96% for normal seed, 92% for fine fissure seed and 87% for unclosed seed. The error of a category include samples belonging to the category were recognized as belonging to the other categories, samples belonging to the other categories were recognized as belonging to the category and samples whose “A surface” or “B surface” were recognized wrongly. The algorithm was proved to be insensitive to white background or black background. The difference of recognition accuracies was insignificant among the five varieties also.

Error analysis

The actual cause of error in this experiment was primarily attributed to the natural attitude of samples in the camera field during image acquisition. The recognition accuracy of samples with glume joint in the middle of the seed region was very high. Leaning seed with glume joint deviated so far to one side of the seed region as to coincide with the edge of the seed in the image was the main source of classification error.

CONCLUSION

In this attempt to develop image-processing algorithms for inspecting rice seeds with incompletely closed glumes, packed images of rice seed were acquisitioned with a machine vision system. Hough transformation was used to extract image features which best correlated with the seed characteristics for identification. The group number of post-processing results was proved to be good indicators of incompletely closed glumes. An image-processing algorithm was developed and implemented with all image sets involved five rice seed varieties. Experimental results indicated desired classification for the rice seed characteristics. The algorithms achieved average accuracy of 96% for normal seeds, 92% for seeds with fine fissure and 87% for seeds with unclosed glumes. The group of post-processing Hough transform as a special feature for inspecting rice seed with incompletely closed glumes was applied to different seed varieties and appeared to be insensitive to the color of the background.

References

Casady, W.W., Paulsen, M.R., Reid, J.F., Sinclair, J.B., 1992. A trainable algorithm for inspection of soybean seed quality. *Trans. ASAE*, **35**(6):2027-2034.

Gunasekaran, S., Cooper, T.M., Berlage, A.G., 1988a. Evaluating quality factors of corn and soybean using a computer vision system. *Trans. ASAE*, **31**(4):1264-1271.

Gunasekaran, S., Cooper, T.M., Berlage, A.G., 1988b. Soybean seed coat and cotyledon crack detection by image processing. *J. Agric. Eng. Res.*, **41**:139-148.

Lai, F.S., Zayas, I., Pomeranz, Y., 1986. Application of pattern recognition techniques in the analysis of cereal grains. *Cereal Chem.*, **63**(2):168-172.

Liao, K., Paulsen, M.R., Reid, J.F., Ni, B., Bonifacio-Maghirang, E.P., 1993. Corn kernel breakage classification by machine vision. *Trans. ASAE*, **36**(6):1949-1953.

Ng, H.F., Wilcke, W.F., Morey, R.V., Lang., J.P., 1998. Machine vision evaluation of corn kernel mechanical and mold damage. *Trans. ASAE*, **41**(2):425-420.

Neuman, M., Sapirstein, H.D., Shwedyck, E., Bushuk, W., 1987. Discrimination of wheat class and variety by digital image analysis of whole grain samples. *J. Cereal Sci.*, **6**:125-132.

Sapirstein, H.D., Neuman, M., Wright, E.H., Shwedyk, E., Bushuk, W., 1987. An instrumental system for cereal grain classification using digital image analysis. *J. Cereal Sci*., **6**:3-14.

Satake, T., Furuya, T., Shimohara, T., 1992. Study on the development of neuroprocessor for the quality evaluation of brown rice. *J. Japanese Soc. Agric. Machinery*, **54**(4):67-75.

Zayas, I., Pomeranz, L.Y., Lai, F.S., 1985. Discrimination between Arthur and Arkan wheats by image analysis. *Cereal Chem.*, **62**:478.

Zayas, I., Converse, H., Steele, J., 1990. Discrimination of Whole from broken corn kernels with image analysis. *Trans. ASAE*, **33**(5):1642-1646.

Zayas, I., Martin, C.R., Steele, J.L., Katsevich, A., 1996. Wheat classification using image analysis and crush-force parameters. *Trans. ASAE*, **39**:2199-2204.