Plant Seed Image Recognition System (PSIRS)

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***Abstract*—The objective of this research is to develop a computer system, which can recognize a plant seed image. The system is called "Plant seed image recognition system (PSIRS)". The system consists of 5 processing modules, namely: 1) image acquisition, 2) image preprocessing, 3) feature extraction, 4) image recognition, and 5) display result. The experiment was conducted on more than 1,000 seed images by employing the Euclidean distance technique to recognize them. The precision rates of the system were 95.1 percent for correct matching in the training data set and 64.0 percent for unknown in the untrained data set. The average access time was 8.79 seconds per image.**

***Index Terms*—Plant seed, seed recognition, image processing.**

I. Introduction

Thailand is an agricultural country which can produce a huge number of food products each year e.g. cereals, flowers, vegetables, fruits, rubber etc. Some food products germinate by using their seed. But it is very difficult to identify a variety of plant seeds because of a huge number of plant species. Therefore, the objective of this research is to develop a computer system, which can recognize some Thai plant seeds by using only a plant seed image.

Due to the advance of video camera technology, people can take a digital picture or digital video stream in any place and any time with a very simple camera or mobile phone. A digital image is not only produced by using easy and inexpensive equipment but also convenient to process by a computer system. Therefore, this research employs a simple digital camera to capture a plant seed and applies a simple image processing technique to recognize some Thai plant seeds.

II. Literature Reviews

There are many researchers who develop a variety of plant seed recognition systems by applying many image processing methods e.g. an artificial neural network, a rule-based system, and a Euclidean distance techniques etc. The brief details of each technique are as the following:

Manuscript received August 10, 2011, revised October 18, 2011.

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A. Artificial Neural Network

M. Jedra et al. (2000) mapped cereal seeds into a temporal organization map. Then the system applied a Time delay neural network (TDNN) to recognize seed varieties. The precision of their system was 98.0 percent [1].

H. Hashim et al. (2010) extracted a color, a shape, and a size feature of the rubber seed (series RRIM2000 in Malaysia). Then the system applied an artificial neural network (ANN) to recognize them. The precision of their system was 84.0 percent [2].

Z.Z. Han and Y.G. Zhao (2009) developed a peanut seed recognition system. The system extracted peanut texture and color. After that the system applied an artificial neural network (ANN) to recognize the peanut seeds, with the precision of 93.0 percent [3].

C.J. Shi and G.G. Ji (2009) extracted three main weed seed features, which are seed area, seed perimeter, and axis to the enclosing seed rectangle. Then the system used a back propagation neural network (BPNN) to recognize the weed seeds image, with the precision of 94.0 percent [4].

W. Zhao and J. Wang (2010) identified weed seeds by using morphological characteristics and a back propagation neural network. The system's recognition rate was 96 percent [5].

P.M. Granitto et al. (2004) applied morphological, color and texture characteristics to identify weed seeds with the precision rate of 98 percent [6].

B. Rule-Based System

J.W. Li et al. (2008) developed the rapeseed recognition system. It used only rapeseed color features i.e. RGB (red, green, blue), HSV (hue, saturation, value) and NCM (nine color model). After that, the system employed a rule-based system to recognize the rapeseed, with the precision of 92.72 percent [7].

C. Euclidean Distance Method

M. You and C. Cai (2009) used principal component analysis (PCA) with the Euclidean distance technique to classify weed seeds [8].

F.F. Zhao et al. (2009) applied the Euclidean distance technique to recognize weed seeds by using their principal component analysis (PCA), with the precision of 96 percent [9-10].

C.J. Shi and G.G. Ji (2009) identified leguminous weed seeds by using the Euclidean distance method. The system was conducted on 60 kinds of weed seeds [11].

A. Ouiza et al. (2007) used seeds size, form and texture features to recognize four kinds of seeds, which are oats, corn, lentil and barley. The system applied the Euclidean distance technique, with the precision rate of 78 percent [12].

Based on the literature reviews above, this research will apply various seed features, e.g. texture, color, size and shape, etc. following the previous research. Moreover, the research will apply the Euclidean distance method to recognize Thai plant seeds because it is easy to implement. The system implementation details will be presented in the next section.

III. Methodology

This part describes the process of analysis and design, which describes the PSIRS system conceptual diagram and system structure chart. The details of each element are described below.

A. System Conceptual Diagram

The PSIRS starts with user taking a seed image by using a digital camera. Then the seed image is sent to a computer system for recognizing. After that, the system compares the seed image with all seed images in the system database. Finally, the PSIRS displays the recognition results, as shown in Fig. 1.

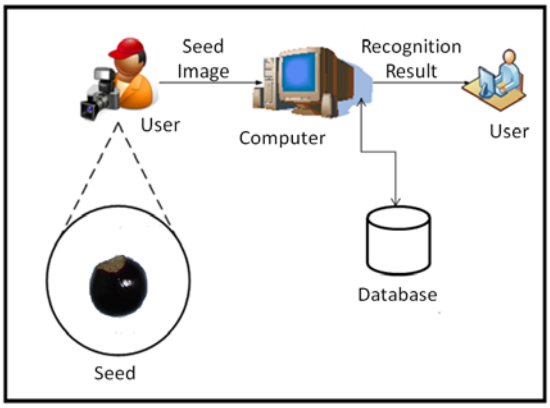

Fig. 1. System conceptual diagram.

B. System Structure Chart

To provide a better understanding and more detail of each operation of the PSIRS, the system structure chart elaborating on how each model works is shown in Fig. 2. The PSIRS consists of five main process modules. They are 1) image acquisition, 2) image preprocessing, 3) feature extraction, 4) image recognition, and 5) display result. Each process module has the following details.

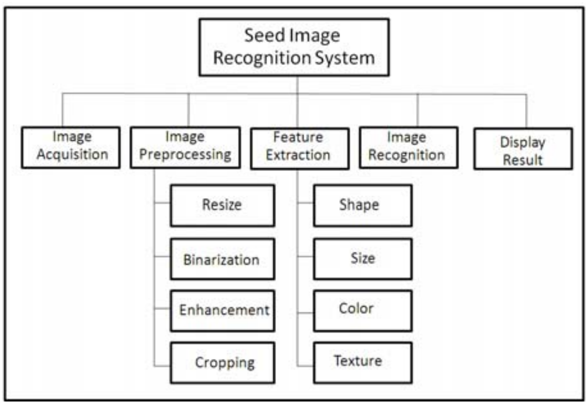

Fig. 2. System structure chart.

1) Image acquisition

A seed image is taken in a bird-eyes-view angle. The seed is put on frosted glass, with the distance between a seed and camera of 30 centimeters. The camera has been set to be zooming 1.5 pixels with the slow flash. The PSIRS reduces a seed shadow by taking a seed photo on frosted glass.

2) Image preprocessing

The image preprocessing module consists of three sub-modules, which are 1) resizing, 2) binarization, and 3) enhancement. Each sub-module has the following details.

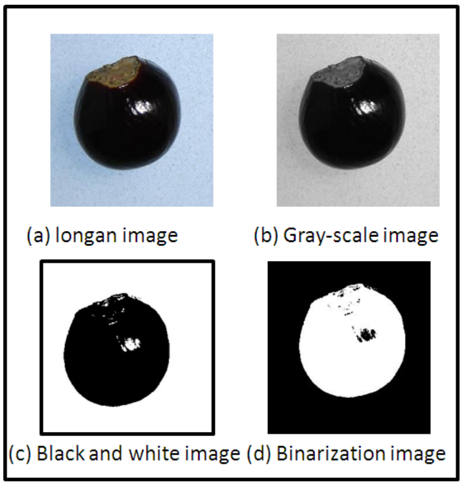

Fig. 3. Transform a seed RGB image into a seed binarizatation image.

a) Image Resize

The input images may have different sizes which can affect the results. The system then resizes every image to 400 pixels in height, the ratio preserved in order to maintain consistence and reduce processing time.

b) Image Binarization

The system changes an RGB color image to a gray-scale image (as shown in Fig. 3(a) - 3(b)). Then the system transforms the gray-scale image into a binary image or a black-and-white image (as shown in Fig. 3(c)). Finally, the system converts the binary image to a binarization image, as shown in Fig. 3(d).

c) Binary Image Enhancement

The system performs morphological closing to close any opening area in the seed image. Then the system fills holes and removes noise to get an enhanced binary image (as shown in Fig. 4(a) – 4(b)).

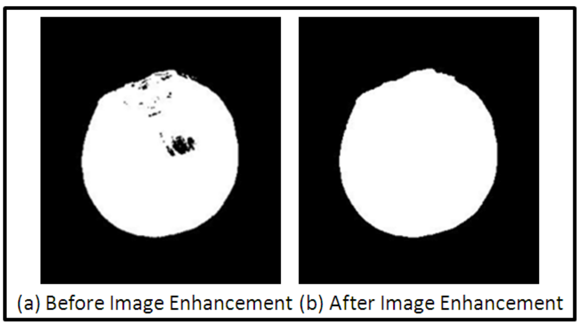

Fig. 4. A seed before & after image enhancement.

d) Image Cropping

The system builds a rectangle, which can cover and fit to each side of a seed, as shown in Fig. 5(a) and 5(b).

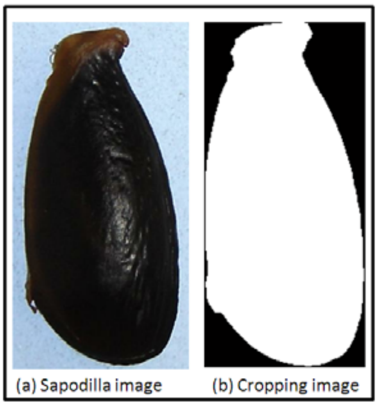

Fig. 5. Seed cropping image.

3) *Feature extraction*

The feature extraction finds four seed features, namely: 1) shape, 2) size, 3) color, and 4) texture. Each feature has the following details.

a) Shape extraction

There are four sub-features in the shape feature, namely: 1) seed boundary, 2) seed edge, 3) seed roundness, and 4) seed ripples. Each sub-feature has the following details.

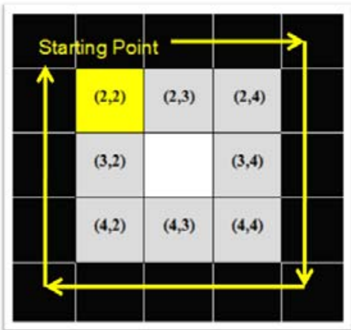

Fig. 6. Boundary tracking direction.

1. Seed boundary

The PSIRS finds seed boundary by using cropping image as shown in Fig. 5. Then the system counts white pixels, which is the boundary of a seed, by moving in the following directions 1) from left to right, 2) from top to bottom, 3) from right to left, and 4) from bottom to top, as shown in Fig. 6.

2. Seed edge

The system applies the Sobel edge detection to a gray-scale seed image by using threshold values 0.05, 0.03 and 0.01, respectively (Fig. 7). Then the system excludes the boundary by using an AND operation with the eroded seed image. After that, the system counts the remaining pixels and divides them with the area of the seed.

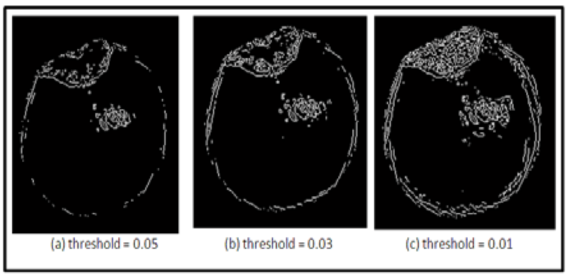

Fig. 7. Sobel edge detection with different threshold values.

3. Seed roundness

The roundness measures the roundness of a seed. The seed roundness value can be calculated by Equation 1.

$$R = (4 \pi * A) / B^2 \tag{1}$$

where R = roundness value

A = seed area
B = seed boundary

A roundness value is to measure the roundness of an object.

4. Seed ripples

The ripples features describe the fluctuation of the seed boundary, which can be calculated by finding the differences between the seed image and the averaged boundary seed image. The averaged seed boundary can be calculated by the seed boundary coordinates in order to find the range of the boundary. The range of the boundary formula is calculated by the following Equation.

$$R = B / 10 \tag{2}$$

where R = range of seed boundary
B = length of seed boundary

After the system gets the differences, it performs an image opening to filter out the narrow area and remove any object which has fewer than 10 pixels. Then the image is called a ripple image, as shown in Fig. 8 (d). The ripple features are divided into two sub-features.

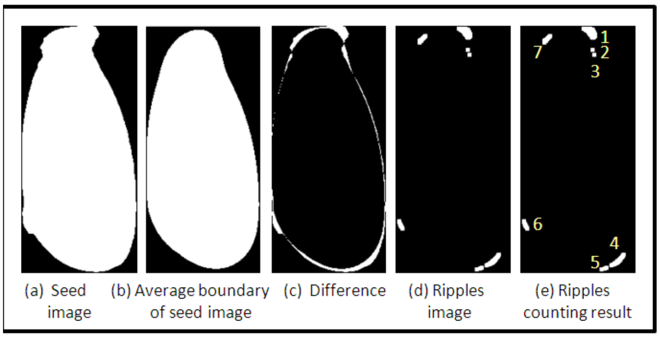

Fig. 8. Ripple images (e) ripples counting results (d) ripple image, (c) difference between (b) average boundary and (a) seed image.

i. Ripples counting

The ripples are the remaining objects in the ripple image, as shown in Fig. 8(d). The result of counting the number of ripples is shown in Fig. 8(e).

ii. Ripples pixels counting

This process counts all the white pixels in all ripples.

b) Size feature

The PSIRS divides a seed image into two equal areas by a horizontal line (Fig. 9) and uses the upper seed area ratio and the lower seed area ratio for two more seed features.

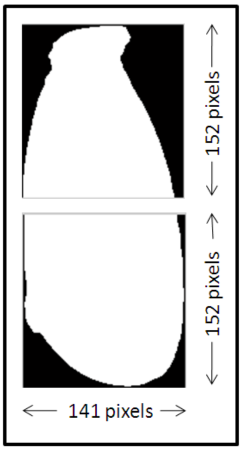

Fig. 9. Upper (top) and lower (bottom) seed area ratio features.

1. The upper seed area ratio

This ratio is calculated by dividing the upper seed area by the upper image area. The upper seed area is found by counting the number of white pixels in the upper seed image

2. The lower seed area ratio

This ratio is calculated by dividing the lower seed area by the lower image area. The lower seed area is found by counting the number of white pixels in the lower seed image. Based on the half-seed area ratio in Fig. 9, the system calculates both area ratios:

Half-seed area	= 152 X 141
	= 21,432 pixels
Upper seed area	= 14,142 pixels
Upper seed ratio	= 14,142 / 21,432
	= 0.6598
Lower seed area	= 18,173 pixels
Lower seed ratio	= 18,173 / 21,432
	= 0.8479

c) Color feature

The PSIRS color features are divided into two sub-features, namely: the average RGB color feature and the average L*a*b* color feature. The PSIRS transforms the RGB color space into an L*a*b* color space. Taking into account only the seed pixels, the system finds the average L*, a* and b* values for three more seed color features by applying Equations 3 to 8 [13]:

X = k1R+k2G+k3B (3)
Y = k4R+k5G+k6B (4)
Z = k7R+k8G+k9B (5)
L* = 116(Y/Yn)1/3 -16 (6)
a* = 500[(X/Xn) 1/3 -(Y/Yn) 1/3] (7)
b* = 200[(Y/Yn) 1/3 -(Z/Zn) 1/3] (8)

where

R, G, B = the gray pixel in three components (red, green and blue);

X, Y,Z = the tri-stimulus values in the Commission Internationale de l' Eclairage (CIE1931) system;

k1–k9 = constants (relating to the standard white and the three primary colors);

Xn, Yn, Zn = tri-stimulus values of standard white color;

L* = average value of the luminance;

a*, = average value of the chromaticity channel a

b* = average value of the chromaticity channel b.

d) Texture feature

The PSIRS uses gray level co-occurrence matrices (GLCM) for measuring the seed surface texture. The GLCM in this research applies five texture features, namely: 1) energy, 2) entropy, 3) contrast, 4) homogeneity, and 5) correlation. Each texture features calculated based on Equations 9 -13 [14].

where

P i,j = entry in a normalized gray-tone spatial-dependence matrix.

N = number of distinct gray levels in the quantized image.

1. Energy texture feature

The energy texture is the sum of squared elements in the GLCM. The energy texture also known as uniformity or the angular second moment. The energy can be calculated by Equation 9.

$$\mu_i = \sum_{i,j=0}^{N-1} i P_{i,j}, \ \mu_j = \sum_{i,j=0}^{N-1} j P_{i,j} \qquad (9)$$

2. Entropy texture feature

The entropy is a statistical measure of randomness that can be used to characterize the texture of the input image. The entropy can be found by Equation 10.

$$\sum_{i,j=0}^{N-1} P_{i,j}(-\ln P_{i,j}) \qquad (10)$$

3. Contrast texture feature

The contrast texture measures the local variations in the GLCM. The contrast texture can be calculated by Equation 11.

$$\sum_{i,j=0}^{N-1} P_{i,j}(i-j)^2 \qquad (11)$$

4. Homogeneity texture feature

The homogeneity measures the closeness of the distribution of elements in the GLCM to the GLCM diagonal. The homogeneity can be calculated by Equation 12.

$$\sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1+(i-j)^2} \qquad (12)$$

5. Correlation texture feature

The correlation texture feature measures the linear dependency of gray levels on those of neighboring pixels. The correlation is calculated by Equation 13.

$$\sum_{i,j=0}^{N-1} P_{i,j} \left(\frac{(i-\mu_i)(j-\mu_j)}{\sigma_i \sigma_j} \right) \qquad (13)$$

where

μ_x, μ_y, σ_x and σ_y = the means and standard deviations of p_x and p_y

4) Image recognition

The PSIRS employs the Euclidean distance to measure the distance between every feature of a sample data set and every feature of each training data set in the system database. The Euclidean distance can be calculated by using Equation 14.

$$ED = \sqrt{\sum_{i=1}^{n} (X_i - Y_i)^2} \qquad (14)$$

where

ED is the Euclidean distance value,
n is number of features,
X_i is a value of feature i in the system database,
Y_i is a value of feature i of a sample image.

5) Display result

The display result process shows seed recognition results. The graphic user interface (GUI) of the system is shown in Fig. 10, which has the following details.

a) Image box

There are two image boxes, namely: 1) input seed sample image box (label number 1), and 2) recognition image box (label number 2).

b) Text box

There are five text boxes, which are: 1) browse image file text box (label number 3), 2) recognition seed name text box (label number 4), 3) seed property text box (label number 5), 4) preprocessing time text box (label number 6), and 5) recognition time text box (label number 7).

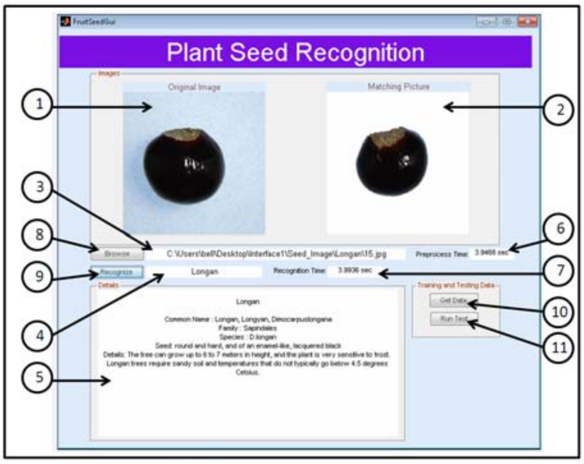

Fig. 10. the GUI of the PSIRS.

c) Command button

There are four command buttons, namely: 1) browse image file button (label number 8), 2) recognition process button (label number 9), 3) get data button for training system database (label number 10), and 4) run test button for running the training data set (label number 11).

IV. Experimental Results

The experiment was conducted on 15 species of seeds, which are divided into ten species for a training data set, and five species for an untrained data set. The system database contains 600 seed images in ten species of plants. In the training data set and untrained data set, each species used 100 and 10 samples, respectively, to test the system. The precision rates of the training data set were 95.1%, 1.8% and 3.1% for match, mismatch and unknown, respectively (as shown in Table I). For the untrained data set, the precision rates were 36.0% and 64.0% for mismatch and unknown, respectively (as shown in Table II). The average access time was 8.79 seconds per image.

TABLE I: Precision Rates for Training Data Set

Seed Name	T	M	S	U
Cantaloupe	100	85	0	15
Corn	100	96	0	4
Legume	100	99	0	1
Lemon	100	97	2	1
Longan	100	97	3	0
Orange	100	85	6	9
Papaya	100	98	1	1
Sapodilla	100	99	1	0
Tamarind	100	85	5	0
Watermelon	100	100	0	0
Sum	1000	951	18	31

where T= Number of Testing data, M= Match, S=Mismatch, and U=Unknown

TABLE II: Precision Rates for Untrained Data Set

Seed Name	T	M	S	U
Cucumber	10	0	7	3
Grape	10	0	0	10
Kaffir lime	10	0	10	0
Rice	10	0	1	9
Star Gooseberrry	10	0	0	10
Sum	50	0	18	32

where T= Number of Testing data, M= Match, S=Mismatch, and U=Unknown

V. Conclusion

In this paper, the PSIRS fulfilled the research objective by extracting four main seed features, namely: 1) shape, 2) size, 3) color, and 4) texture, for the recognition of plant seed samples. The PSIRS used 15 species of plant seeds to test the system. The precision rates of the system were 95.10 percent for a matching in a training dataset and 64.00 percent for an unknown in an untrained data set. The average access time was 8.79 seconds/image.

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