(a)

(b)

(c)

(d)

Fig. 1a-1d Typical image of weedy rice seed variants

Pattern recognition of machine learning is performed using the algorithm for seed and grain quality evaluation [7]. One of the most common techniques is by the artificial neural network (ANN). The ANN is developed to replicate the human decision-making process based on the input data fed into the algorithm. The architecture of ANN consists of three distinct layers; the input layer that connects to hidden neurons layer which connects to the output layer. The network processes the data based on the weights obtained from the pattern set in the training process.

The used of ANN in the classification analysis of agro-based product as well as in other application has been widely used such as in the classification of Chinese rice seed varieties [11], apple grading [12], discrimination of rapeseed varieties [13], olive fruits recognition [14], detection of segmentation points of Arabic Words [15] and face recognition [16].

The use of such techniques in identifying varieties and objects based on the acquired images has proven to be a potential to for the development of an automated identification system for seed verification test in the laboratory to improve the existing manual inspection. Thus, this study aimed to adopt image processing technique to extract colour features of individual rice seed images and ANN to identify commonly used local rice seed varieties of MR 219 and MR 269.

II. MATERIAL AND METHOD

The procedure to determine rice seed varieties of MR 219 and MR 269 was the collection of rice seed samples, image acquisition, image processing and segmentation; colour features extraction and classification. The approached methodology is as summarized in the flowchart of Fig. 2.
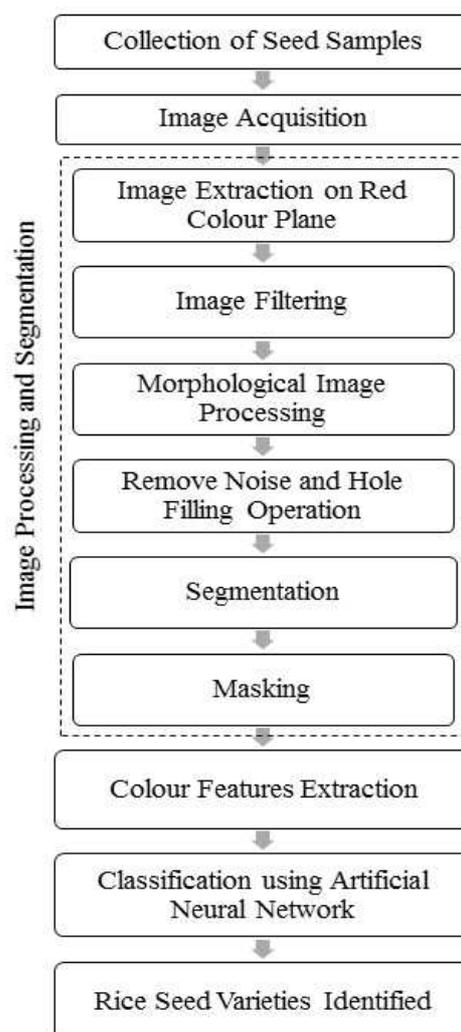

Fig. 2 Methodology flowchart

A. Collection of Rice Seed Samples

The rice seed samples of MR 219 and MR 269 varieties were collected from an authorized local seed supplier in a sealed 20-kg seed bag. The rice seed samples consisted of 200 seed grain per variety were selected individually by visual inspection to ensure the purity of seed variety.

B. Image Acquisition

In image acquisition, a charge coupled device (CCD) Basler camera (acA 1600-60GC) was used with a fitted lens of 16 mm focal length. The camera was mounted on top of a black box perpendicular to the position of the seed plate. The field of view of the camera was adjusted to acquire 10 rice seed per frame. In a single frame, the rice seeds were arranged in 2 x 5 matrix on a fluorescent green 3D printed seed plate. In the black box, two light emitting diodes (LED) bulbs of 6400 K colour temperature were installed on both sides of the box. The experimental set up of the computer vision system is as shown in Fig. 3. In total, 20 images in Red, Green, and Blue (RGB) colour model containing 200 individual seeds were acquired in 1000 x 1200 pixels and saved as Portable Network Graphic (PNG) file format into a personal computer.
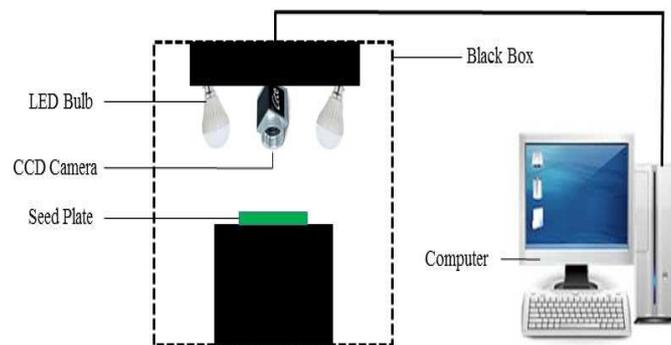

Fig. 3 Computer vision system

C. Image Processing and Segmentation

LabVIEW 2013 [17] software was used as a programming tool for image processing, segmentation and colour feature extraction process.

1) Image Processing

In the program, the acquired images were processed to enhance the quality of the acquired images. The image was first extracted in the red colour plane using Image Acquisition (IMAQ) Extract Single Colour Plane VI. The image was then converted to a greyscale image and filtered using IMAQ Convulate VI to enhance the edge contrast and sharpen the image. In this process, Laplacian filter of 3 x 3 matrix size kernel with kernel number 5 was selected based on the visual test [18].

The morphological image processing procedure such as dilation operation was then carried out to close the contours of individual seed images using IMAQ Morphology IV function was used to perform primary morphology transformations.

Later, IMAQ Particle Filter 3 function was used to remove noisy particles formed on the background image, and hole filling operation was carried out to fill any holes in the seed images with pixel value 1.

2) Image Segmentation

Finally, the seed images were separated from the background through image segmentation process to identify the region of interest [19] using IMAQ Threshold IV. In determining the threshold range of the greyscale image in between 0 to 255 grey level value, manual threshold method was used as the acquired images has good contrast between the seed images and its background colour. In this process, the pixel values of the image were isolated into two separate regions; the particle region consisted of the seed images and the background region. Thus, any pixel value outside the defined range will become pixel value 0 while any pixel value lied in the threshold range becomes 1. The resulted image from segmentation procedure was binary image consisted of value 0 for background and 1 for seed images.

3) Masking

After segmentation, the processed image source that is corresponding to a non-zero-pixel value was masked to display the seed images in RGB format. The sample image before and after image processing procedure for individual seed kernel of MR 219 is as shown in Fig. 4 and Fig. 5 respectively.

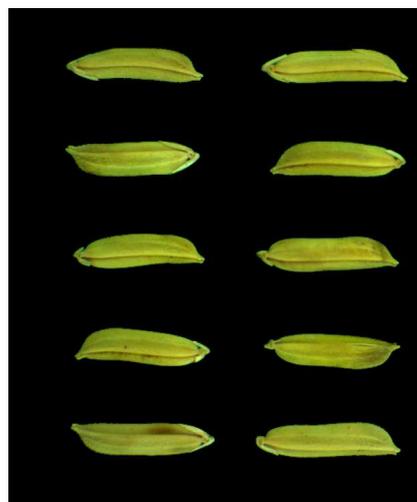Fig. 4 Sample image acquired using CCD camera for MR 219

Fig. 5 Sample image after image processing procedure, segmentation, and masking for MR 219

D. Colour Features Extraction

The processed rice seed images of MR 219 and MR 269 were used in colour feature extraction process to obtain seven colour parameters such as red (R), green (G) and blue (B) in RGB colour space; hue (H), saturation (S), intensity (I), and value (V) in HIS and HSV colour space respectively in term of mean values using IMAQ Colour Histogram VI function in the LabVIEW. Then, the extracted data were saved in a Microsoft Excel data sheet for further analysis.

E. Identification of Rice Seed Varieties

The analysis to determine the rice seed varieties based on the extracted colour features was carried out using ANN Toolbox in MATLAB software. The data was divided into 3 sets of data consisted of 70% training, 15% validation and 15% testing data sets. Numbers of hidden layers were tested using 5, 10, 15, 20, 25, 30, 35, 40 and 45 hidden neurons. Based on the analysis, the number of hidden neurons yielded with the lowest mean squared error (MSE) was chosen for further ANN analysis to obtain the best model for the determination of rice seed according to its varietal groupings.

The two-layer feed-forward network consisted of sigmoid hidden neurons followed by an output layer neurons were used in the analysis. The typical scheme of ANN structure for 40 hidden neurons used in the Neural Network Toolbox is as shown in Fig. 6. The ANN was trained using scaled conjugated gradient back propagation method. In the analysis, the stopping criteria of the training network were set using default setting which automatically ended when the generalization process achieved the optimum accuracy level, thus improving the accuracy of validation data set.
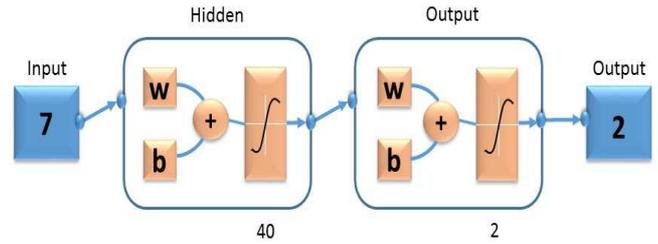

Fig. 6 ANN scheme for 40 hidden neurons

III. RESULTS AND DISCUSSION

The acquired images of individual rice seeds were isolated from the background using several image processing procedures. The summary of extracted colour features data and the box plot analysis of MR 219, and MR 269 images are as summarized in Table 1 and 2 and Fig. 7 to 10 respectively. From Table 1 and 2, the colour features extracted from MR 219 and MR 269 differed in their respective colour features values. The differences provide the potential to differentiate rice varieties according to their colour features. Such differences in the extracted colour features of the two varieties are statistically demonstrated by the box plot in Fig. 7 to 10.

TABLE I
THE EXTRACTED COLOUR FEATURES FOR MR 219 SEED IMAGES

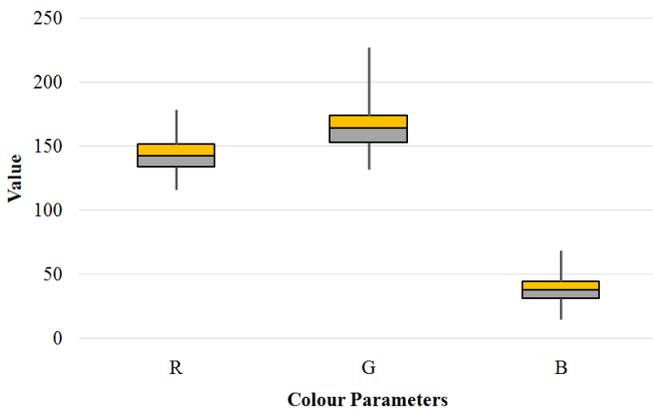| Colour Features	Mean	Standard Deviation	Minimum Value	First Quartile	Median	Third Quartile	Maximum Value
R	143.3	11.9	116.1	134.1	142.5	151.6	178.7
G	164.8	16.4	132.2	153.0	164.1	174.0	227.5
B	38.8	10.3	15.0	31.3	37.8	44.7	69.2
H	50.0°	2.8°	42.3°	48.1°	49.8°	51.5°	60.5°
S	168.7	13.8	130.9	159.4	168.8	176.7	210.2
I	102.2	12.4	76.4	92.9	101.7	109.9	148.0
V	166.3	15.8	134.5	155.6	165.0	174.6	227.6

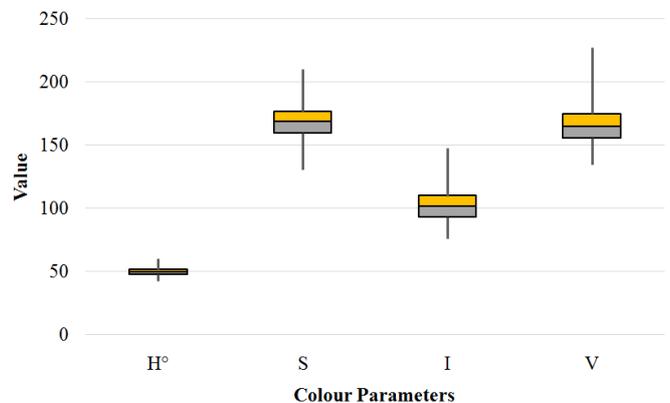Fig. 7 Box plot analysis of R, G and B colour parameters for MR 219

Fig. 8 Box plot analysis of H, S, I and V colour parameters for MR 219

TABLE II
THE EXTRACTED COLOUR FEATURES FOR MR 269 SEED IMAGES

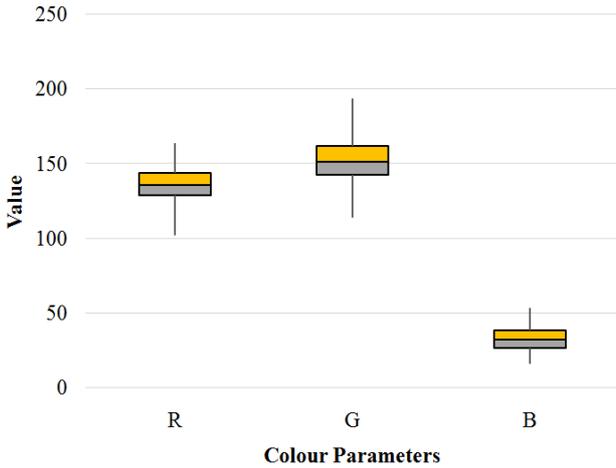| Colour Features	Mean	Standard Deviation	Minimum Value	First Quartile	Median	Third Quartile	Maximum Value
R	136.2	11.4	102.1	128.8	135.6	143.8	163.6
G	152.0	14.2	114.2	142.7	151.2	162.0	193.5
B	32.8	7.9	15.9	26.6	32.2	38.3	53.5
H	48.3°	2.5°	42.9	46.6	48.1	50.0	57.5
S	172.8	12.8	134.6	163.5	172.0	183.2	202.6
I	93.2	10.1	69.5	86.1	92.6	100.1	119.2
V	154.2	13.7	115.9	145.8	153.1	119.2	194.0

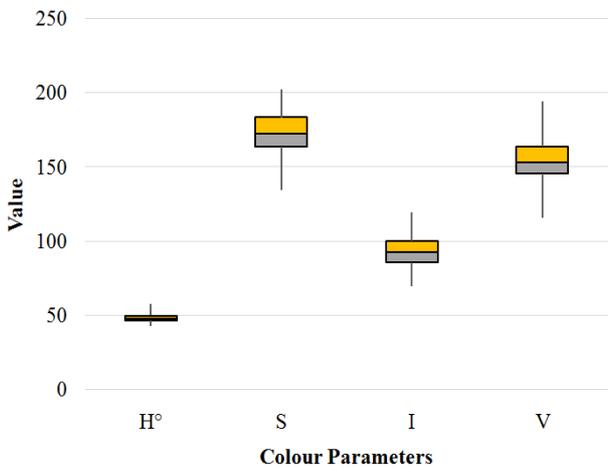Fig. 9 Box plot analysis of R, G and B colour parameters for MR 269

Fig. 10 Box plot analysis of H, S, I and V colour parameters for MR 269

The extracted data were analysed using ANN to obtain the best model to identify the rice seed varieties in the MATLAB ANN Toolbox. Table 3 shows the results of a tested number of hidden neurons. Based on the neural network training utilizing the training and testing dataset using 5, 10, 15, 20, 25, 30, 35, 40 and 45 hidden neurons. The lowest MSE value of 0.1966 was obtained using the 40 hidden neurons with the accuracy of 64.6% and 70.0% for testing and training data sets respectively. Thus, 40 hidden neurons were selected to improve the classification accuracy by retraining the network. Using the 40 hidden neurons, the

retraining process carried out using ANN was repeated until the MSE value falls below a predefined level or until the maximum iteration value is achieved [20].

TABLE III
THE TESTED NUMBER OF HIDDEN NEURONS
WITH THE RESPECTIVE MEAN SQUARED ERROR VALUES

Number of Hidden Neurons	Mean Squared Error (MSE)
5	0.2262
10	0.2355
15	0.1987
20	0.2153
25	0.2168
30	0.2095
35	0.2101
40	0.1966
45	0.2175

The classification accuracy results to identify the rice seed varieties using the retrained network of 40 hidden neurons on training and testing data sets yielded an accuracy of 67.5% (MSE value = 0.20279) and 76.7% accuracy level (MSE value = 0.1885) for testing and training data sets respectively. The details of the classification accuracies obtained from confusion matrix table generated in the MATLAB ANN Toolbox was summarized in Table 4.

Based on the classification results, there was 6.7% increment in accuracy level of testing data set after the network was retrained using 40 hidden neurons. The improvement in accuracy values was due to a random selection of the input data sets after the first training process. Although there exist differences in the extracted colour features, the accuracy levels are considerably lower than the desired level of 90%. It can be concluded that future identification of seed based on the extracted 7 colour features alone would not be sufficient to identify of rice seed varieties. Therefore, larger numbers of extracted colour features are expected to improve the accuracy level as reported by other researchers [2], [6], [7], [21], [22], [23], and [24].

Data Set			Group	Predicted Group		Mean Accuracy	Total
				MR 219	MR 269		
Training	Original	Count	MR 219	96	42		142
			MR 269	49	93		138
		Accuracy (%)	MR 219	69.6	30.4	67.5	100
			MR 269	34.5	65.5		100
	Validation	Count	MR 219	20	17		23
			MR 269	8	15		37
		Accuracy (%)	MR 219	54.1	34.8	58.3	100
			MR 269	45.9	65.2		100
Testing	Original	Count	MR 219	20	5		35
			MR 269	9	26		25
		Accuracy (%)	MR 219	80	25.7	76.7	100
			MR 269	20	74.3		100

IV. CONCLUSIONS

Based on the analysis, the highest accuracy levels achieved were 67.5% (MSE value = 0.20279) and 76.7% accuracy level (MSE value = 0.1885) for testing and training data sets respectively. The accuracy level is low to accurately identify rice seed of different varieties. The inclusion of other colour features extracted directly or their derivative could improve the accuracy level. As a recommendation to improve the classification accuracy, the input parameters of colour features should be increased while the least significant input must be reduced using the principal component analysis. The accuracy level can be further enhanced if other features such as morphology and texture features are incorporated in the classification analysis.

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