Paper

Novel Feature Extraction for Pineapple Ripeness Classification

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Abstract—A novel feature extraction method has been proposed to improve the accuracy of the pineapple ripeness classification process. The methodology consists of six stages, namely: image acquisition, image pre-processing, color extraction, feature selection, classification and evaluation of results. The red element in the RGB model is selected as the threshold value parameter. The ripeness of pineapples is determined based on the percentage share of yellowish scales visible in images presenting the front and the back side of the fruit. The prototype system is capable of classifying pineapples into three main groups: unripe, ripe, and fully ripe. The accuracy of 86.05% has been achieved during experiments.

Keywords—image processing technique, pineapple, ripeness grading.

1. Introduction

With the area of 1,805 hectares, Sarawak is Malaysia's second largest pineapple plantation [1]. The pineapple industry is one of those agricultural sectors that are characterized by high productivity rates and expenditure levels. This means that it is highly recommended for them to implement advanced technologies in their production processes, for example to replace manual processes involving workers with innovative technical solutions. Sarawak still has room for improvement in terms of the technology used in the pineapple industry.

Fruit quality checks are important in the pineapple industry due to great demand levels and highly competitive markets [2]. A traditional method of identifying and grading the ripeness of a pineapple relies on a visual inspection during which the skin color is assessed. Visual inspections are usually conducted by well-trained workers. Such human inspections are inconsistent and subjective [3]. As production volumes grow, the number of cases in which visual inspections are performed inaccurately may increase as well. A human grader may also be inconsistent in terms of the quality of their work, as human eyes may get tired when large quantities of fruit need to be processed.

Therefore, computer-based technologies, such as image processing techniques, are very much needed and should be applied for the purpose of classifying pineapple ripeness levels.

2. Related Work

Several types of color-based models and techniques are used for identification and classification purposes in the agricultural industry. In this paper, the existing techniques that have been relied upon to identify and classify the ripeness of pineapples are discussed and reviewed. These techniques include neural network classification based on color image features, linear classification based on color image features and fuzzy logic classification based on color image features.

Paper [4] proposed a neural network classification based on color image features for classifying pineapple ripeness. Image acquisition in a controlled environment is crucial for the collection of data, because such an environment ensures that any noise compromising image quality may be eliminated and that the image captured is clear and suitable for processing in the subsequent stages of the process. A controlled environment is deemed to consist of a high-definition camera positioned at a fixed distance of 1.5 meters away from the fruit, at an angle of 90° relative to the ground, and with a constant exposure to light throughout the entire process.

During the pre-processing phase, the images are subjected to filtering in order to remove redundant information, such as noise. The background of each image is cropped and resized into a standard resolution to ensure all images may pass through the system. RGB extraction is performed to extract the green color from the RGB channel. It is then converted into grayscale to show the intensity of the image's green component.

During the feature extraction phase, the number of green and red pixels is extracted from a selected region of the image. Next, during the feature selection phase, the range of both yellow and green colors are populated to allow respective counters to count the number of red and green color pixels when a certain pixel lies within the range.

An artificial neural network (ANN) is used during the classification phase. According to [4], ANN is a set of interconnected nodes positioned between the input and the output for a system. In other words, the manner in which ANN is programmed to differentiate between ripe and unripe pineapples mimics the human brain. The ANN-derived result is then processed and is assigned with one of 4 in-

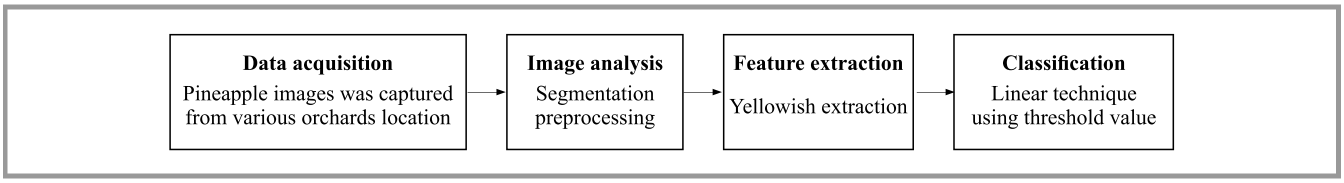

Fig. 1. Pineapple classification methodology using the image processing technique.

dexes. This system differentiates 4 index maturities only instead of 7 indexes requires under the Federal Agricultural Marketing Authority's (FAMA) standard. This is because the fruit start to ripen when their index equals between 4 and 7, while those with the index of 1 to 3 remain greenish, which makes it hard to compare the change of the color of their skin.

This system has successfully classified the ripeness of pineapples using the neural network classification method based on color image features and has reached the accuracy rate of 75%.

[5] has implemented linear classification based on color image features to classify the ripeness index. Figure 1 shows the flow chart of used methodology of classification.

The data was collected from one of the pineapple orchards in Johor and Pahang, Malaysia. The images of N36 pineapples are taken at different angles and then stored in the database for future development of the system. Next, the segmentation pre-processing phase occurred (Fig. 2) [5]. The background of the image was removed because it comprises unwanted data, such as noise, which will affect the color analysis process. Segmentation is necessary because it is used to determine the objects of interest and their boundaries in the image.

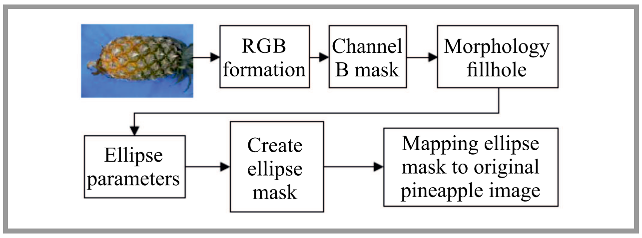

Fig. 2. Pineapple image segmentation process.

The B channel mask is used rather than R and G channel masks to delineate the area of the pineapple because it does not exist in the formation of the pineapple's pixel value which then naturally eliminates the blue background image as shown in Fig. 3d. The image is then converted into a binary image for its later processing with the use of the morphology fillhole method. The purpose of implementing the morphology fillhole method during the segmentation process is to capture the outline of the fruit. The method fails, however, to produce a smooth rounded object after filling the image with white pixels. In other words, the stump and crown are still included in the image after filling it with white pixels. Therefore, a binary ellipse mask is used to overcome this issue and to produce a smooth rounded object, as shown in Fig. 3g. The mask is then mapped onto the original image to obtain the region of interest (ROI), as shown in Fig. 3h.

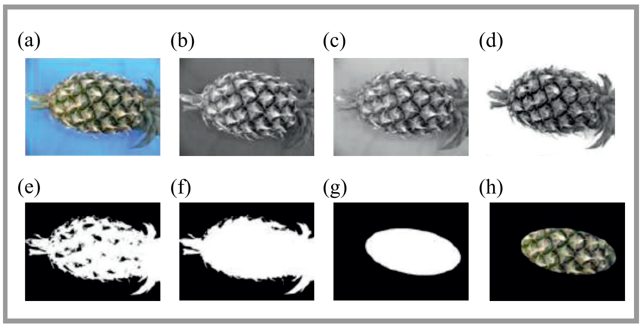

Fig. 3. Segmentation of the pineapple image: (a) original image, (b) red channel, (c) green channel, (d) blue channel, (e) binary image of the blue channel, (f) morphological fillhole, (g) binary ellipse mask, (h) segmented pineapple body using (g) as a mask (see the digital version for color images).

The efficiency of the classification result depends on the feature extracted from the processing stage. The percentage of yellowish scale pixels is the main factor relied upon to measure the maturity index of the pineapple by determining the ratio of all pixel values of ROI. The following formula was used to calculate the percentage of yellowish scale pixels:

$$Py = \frac{py}{pv + pg + py} \times 100\% \,, \tag{1}$$

where py is the number of yellowish scale pixels, pv is the number of dark violet scale pixels and pg is the number of green scale pixels.

The result obtained from Eq. (1) is used to determine the threshold level for classification process. 210 pineapple images were as a training set and the percentage of yellowish scale pixels for each image in each index was calculated and identified. Based on the result of linear classification, the threshold level of yellowish scale pixels is identified and categorized into 7 indexes in line with the FAMA standard.

The efficiency of ripeness classification may be measured by using 700 images of pineapples considered to be a testing set. This system has achieved an overall accuracy and efficiency of 94.29%.

Paper [6] presented a fuzzy logic classification of ripeness based on color image features.

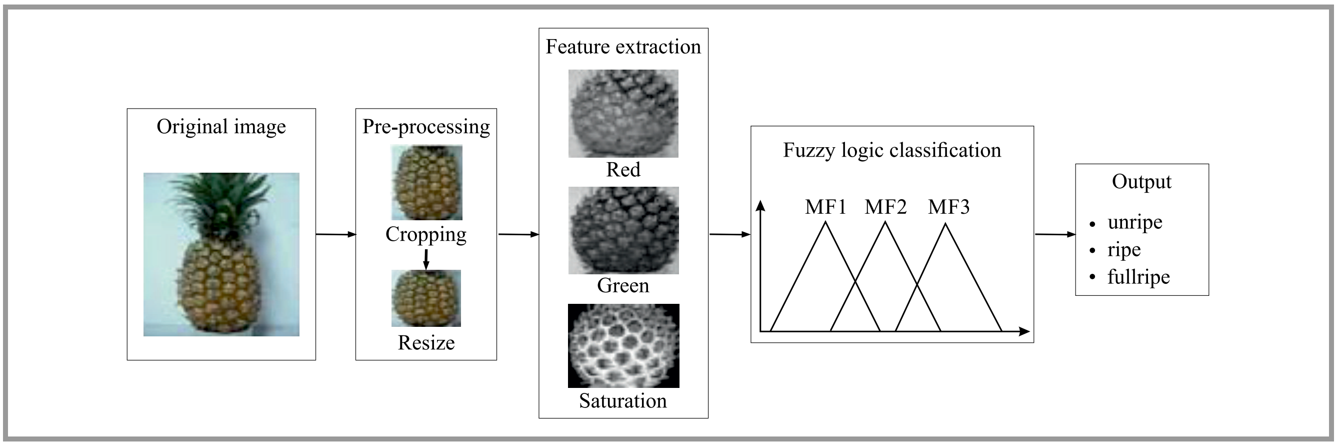

Fig. 4. System flow chart.

Based on Fig. 4, the three main parts of the system include the following: pre-processing, feature extraction, and classification. The procedure starts with data collection, whereby images of Josapine pineapples are obtained in a controlled environment, i.e. with the use of a high-definition camera positioned at a fixed distance from the fruit. Notice that no constant lighting conditions are ensured throughout the process. Therefore, HSI color maps are implemented, because HSI is capable of processing the image even when the lighting conditions are not constant.

Next, each image is filtered to remove redundant information, such as noise, and the unwanted background is cropped because it does not provide any useful information for the classification stage. The size of all images is standardized in 600×600 pixels to ensure good accuracy of the classification process.

During the feature extraction stage, RGB and HSI spectrums are used to extract the necessary information from the image. The entire image is processed with the use of both spectrums. It is converted into the red and green channel in the RGB spectrum, while the HSI spectrum converts the image into the saturation channel.

Before proceeding to the classification stage, feature selection is step that needs to be performed – the data needs to be analyzed in order to meet the specific needs of the project. Data extracted during feature extraction stage is filtered and analyzed within a specific range of red, green and saturation channels. Other channels, such as blue, hue and intensity channel, are not taken in consideration because they do not provide any information needed. When a certain pixel lies within the range, the counters will count the number of pixels within the respective channels.

In the classification stage, fuzzy logic is used as a tool to map the input into a pattern and to match the data accordingly, based on a specific parameter setup, to generate an output. This project uses Matlab software to apply the fuzzy logic features to accept three values from red, green and saturation channels and to generate one output using a Mamdani-style system. Classification is performed based on ripeness and maturity levels. This method has achieved average accuracy of 85% for ripe and unripe fruit and 100% accuracy for fully ripe fruit.

2.1. Analysis of Review

The superior features of three different types of color models and ripeness classification techniques reviewed above will be taken into consideration for the purpose of the project. Images taken in a controlled environment are required in order to obtain more accurate and consistent ripeness classification results. The background should be removed to ensure that the results the fruit classification procedure are accurate. After reviewing the techniques introduced in the previous section, all their superior features, such as color models, strengths and weaknesses are compared with each other. Each technique is summarized in Table 1.

By using the neural network classification method, the fruit may be categorized into four different types of ripeness, namely unripe, early ripe, ripe and overripe. The linear classification method is capable of assigning pineapples to up to seven categories, while the fuzzy logic classification method assigns the fruit into three major groups, i.e. unripe, ripe and fully ripe. Hence, in this project, pineapples will be graded and categorized into three major groups, namely unripe, ripe and fully ripe.

Furthermore, the RGB color model will be used in this project. This is because it serves as a good point of departure and is also well-known for most image applications used nowadays. Moreover, the RGB color model is capable of calculating the percentage of yellowish pixels through the red channel, based on an appropriate threshold value, and the ripeness of pineapple is usually determined by humans based on their yellowish skin color. Hence, the RGB model is the most suitable color model for the project in question.

Instead of using a single vertical line as proposed in [4], multiple diagonal lines will be produced and applied in the prototype as an indicator for grading the degree of ripeness. A training data set will be used to obtain the per-

Table 1
Comparative analysis of the techniques reviewed

Technique	Neural network classification	Linear classification	Fuzzy logic classification
Dataset	Not stated	700	40
Training set	Not stated	210	20
Grades supported	Unripe, early ripe, ripe, overripe	7 levels: immature, early mature, mature, under ripe, early ripe, ripe, overripe	7 levels but categorizes into three major group: unripe, ripe, fully ripe
Color model	RGB	RGB	RGB and HIS
Accuracy of classification	75%	94.29%	85% for unripe and ripe, 100% for overripe
Strengths	Makes the process of data extraction more accurate and easier. Features from two regions of interest are extracted to obtain more accurate classification results.	Able to grade pineapples very accurately. Threshold value is identified to classify the maturity of pineapples.	HSI is able to process the image even when lighting conditions are not constant.
Weaknesses	Works on one type of pineapple (Josapine). Able to assign pineapples into four categories only.	Works on one type of pineapple (N36 only).	Lighting conditions may affect the accuracy of classification.

centage ranges of yellowish pixels for each index. Threshold values will be identified and used for classification of ripeness.

3. Proposed Solution

This section discusses the algorithms proposed for the automated pineapple ripeness grading system and presents the individual stages of the image processing technique, including image acquisition, image pre-processing, color extraction, feature selection, classification of results and their evaluation (Fig. 5).

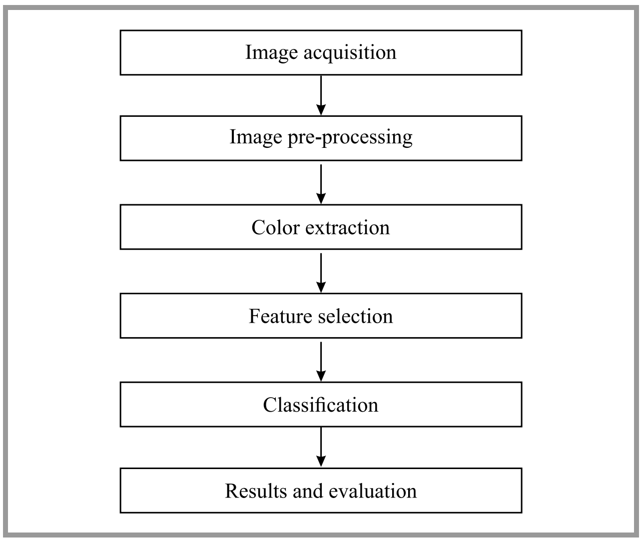

Fig. 5. Process flow of proposed technique.

3.1. Image Acquisition

Image acquisition is the first step of the image processing technique during which the pineapple image is collected. The sample is captured in a controlled environment, against a background that highly contrasts the fruit, at a constant distance from fruit, at an angle of 90° relative to the ground or parallel to the camera.

Such a setup helps reduce the amount of unwanted information, for example, in the form of noise, and ensures that the sample images are clear and suitable for processing during the subsequent stages. If the formats of sample images are different, they will be converted to JPEG for standardization purposes. This particular format is characterized by a small file size, meaning that the processing time is shorter and that efficiency is improved.

Sample images with fruit at different ripeness stages (from unripe to fully ripe) are captured, as shown in Fig. 6. For each category, 2 sample images (front and back side of the pineapple) are taken simultaneously to ensure more accurate classification. It is better to grade both sides of the fruit, as it may not ripe uniformly 86 sample images of 43 pineapples were taken in total and were used for the prototype system in this project.

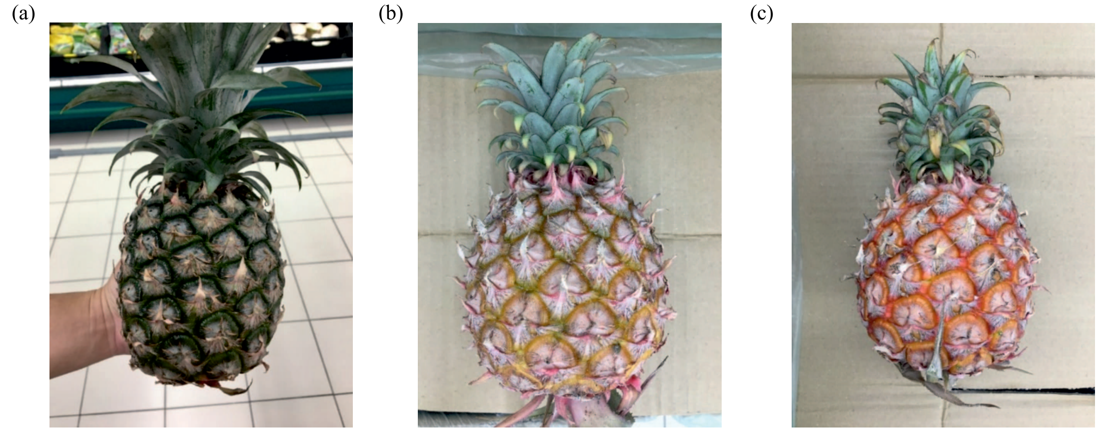

Fig. 6. Pineapple images captured in a controlled environment: (a) unripe, (b) ripe, and (c) fully ripe.

3.2. Image Pre-processing

At this stage, sample images are converted and formatted into an acceptable form in order to be processed during the subsequent stages. For example, they are cropped to remove redundant backgrounds and the crown of the pineapple, thus rendering more accurate results. They are then resized into the format of 600×600 pixels, as shown in Fig. 7, to enhance further processing.

Fig. 7. Redundant background and crown are removed.

3.3. Color Extraction

Here, color extraction will be performed to extract the necessary information from the sample image. The RGB model is applied in this project to extract information required, as it is basic color model most commonly used in image-related applications.

The red elements are extracted from the sample image because they are the main component allowing to classify the pixels of a digital image into two categories, namely yellow and green, based on an appropriate threshold value. Color extraction eliminates background and shortens processing time. Therefore, the red element from the RGB palette is chosen, as its extraction allows to determine the degree of ripeness. In the RGB spectrum, the image will be converted into the red channel to obtain pixel values that are similar to a grayscale image (within the range of 0 to 255) to show the intensity of the color component of the image.

3.4. Feature Selection

The red element of the sample image that was extracted in the previous step will be analyzed to meet the requirements of the project. Before analyzing the red element, six diagonal lines are created, as shown in Fig. 8. Only the pixels that lie along these lines will be analyzed and will be divided into two different categories, namely yellow pixels and green pixels, based on the applicable value of the red element.

Fig. 8. Six diagonal lines drawn across the sample image.

The reason of creating diagonal lines across the sample image, instead of using a single vertical line, is that a pineapple does not have a uniformly yellowish skin color, as shown in Figs. 9 and 10.

Fig. 9. A pineapple with uneven yellowish skin color – more yellowish color on the left.

Fig. 10. A pineapple with uneven yellowish skin color – more yellowish color on the right.

Uneven distribution of yellow on the skin may be a factor that affects the number of yellowish pixels identified if a vertical line is used in the prototype solution. It may be noticed in the examples shown above that the pineapples (depicted in Figs. 9 and 10) are more yellow on the left and on the right, respectively. If a single vertical line was applied in the prototype solution and used on both sample images, as shown in Fig. 11, misclassification could be occurred, as the vertical line does allow the yellowish pixels present on the sides to be taken into consideration.
Furthermore, a vertical line used to analyze the red elements present along that line may produce less ideal results than those achieved based on six diagonal lines. This

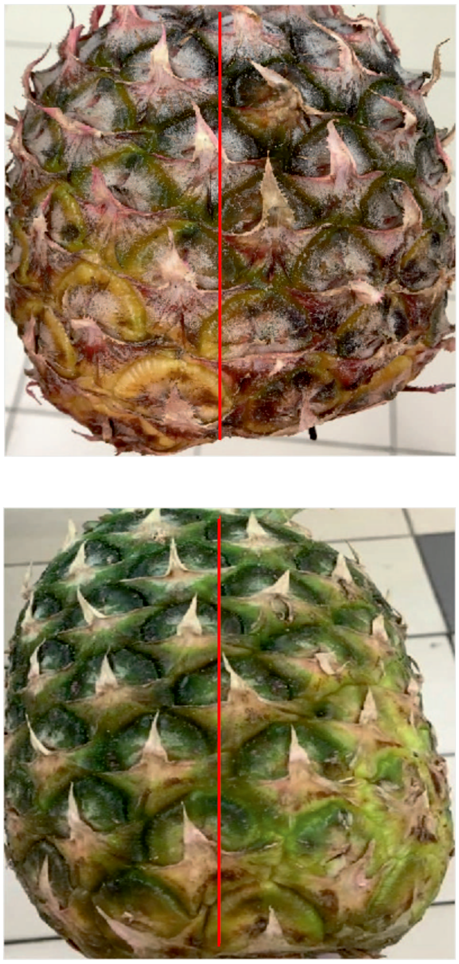

Fig. 11. A vertical line applies on an uneven fruit.

is because a longer section of the vertical line (compared to a diagonal line) runs over the eye of the pineapple, as shown in Fig. 12, and the eye of the fruit does not provide

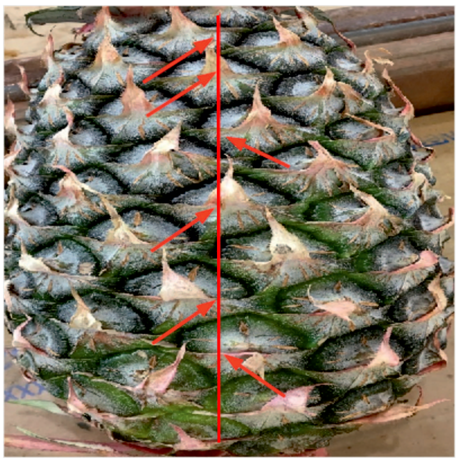

Fig. 12. Eye of the pineapple covered by the vertical line.

any important information for grading its ripeness. Hence, six diagonal lines are created and applied in the prototype solution to avoid the eye of the pineapple and to reduce the probability of misclassification errors as well as to increase the accuracy of the percentage of yellowish of fruit.

Once the six diagonal lines have been created and imposed on the sample image, the pixels that lie along those lines will be analyzed. Each pixel will contain information of the RGB color space, and each component color has the value between 1 and 255. However, only the red element is extracted and analyzed, because the red element from red channel of the RGB color model is capable of assigning the selected pixel into two different categories, namely yellow pixel and green pixel, based on an appropriate threshold value. These two colors can be considered of interest for our purposes.

The threshold value for the red element is set at 160, determined during preliminary tests. Thus, when the value of specific pixel is lower than that of the threshold, green color counters will be incremented. Otherwise, yellow color counters will be incremented. The flowchart presented in Fig. 13 shows the process of counting the number of green and yellow pixels based on threshold value.

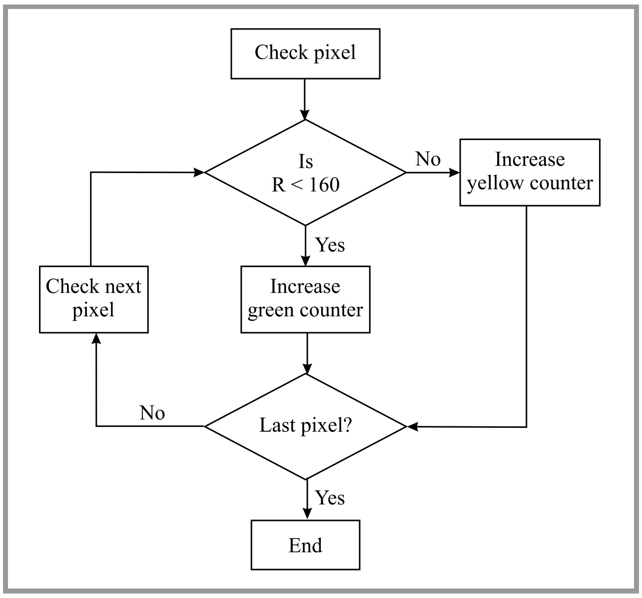

Fig. 13. Flow chart describing the process of counting green and yellow pixels.

This threshold value allows the respective registers to count the number of green and yellow pixels and these values will be used to calculate the percentage share of yellowish scales. Then percentage share will be used during the classification phase to determine ripeness and maturity categories. Six percentage ranges for each diagonal line need to be calculated using the following formula:

$$Y = \frac{N_y}{N_y + N_g} \times 100\% \ , \tag{2}$$

where N_y is the number of yellow pixels and N_g is the number of green pixels.

Once the six percentage ranges have been obtained for the six diagonal lines, the average value may be calculated for each side of the fruit:

$$Y = \frac{Y_1 + Y_2 + Y_3 + Y_4 + Y_5 + Y_6}{6} \ , \tag{3}$$

where Y_1, Y_2, Y_3, Y_4, Y_5, Y_6 represent the six percentage shares of yellowish scales along the diagonal lines.

Nevertheless, the final percentage share of yellowish scales is calculated by taking the average from both sides of the fruit and it can be calculated in the following manner:

$$Y = \frac{Y_{sf} + Y_{sb}}{2} \ , \tag{4}$$

where Y_{sf} represents the percentage share of yellowish scales in the sample image showing the front side of the fruit and Y_{sb} represents the percentage share of yellowish pixels in the sample image showing the back side of the fruit.

3.5. Classification

36 sample images have been taken to determine 7 indexes corresponding to the percentage share yellowish scales in a given pineapple. Among 36 sample images, experts had determined that 5 sample images are used for index 1 to index 6 while 6 sample images are used for index 7 to obtain the percentage of yellowish scales.

During the preliminary test, values ranging from 130 to 200 (at intervals of 10, e.g. 130, 140, 150, ..., 200) were verified. After detailed observations, the value of 160 was selected as most suitable for the needs of the prototype system and was assumed to be the threshold value for determining whether the green or the yellow pixel counter should be incremented. The indexes of 1–7 were defined by experts from the Sarawak Land Consolidation & Rehabilitation Authority (SALCRA). 36 sample images were sent to experts in order to be assigned to the specific ripeness indexes.

Table 2
Percentage shares of yellowish scales

Index	FAMA	Specified range
1	0%	$0\% <$ yellowish $\leq 9.57\%$
2	A little bit	$9.57\% <$ yellowish $\leq 19.86\%$
3	1–2 scales	$19.86\% <$ yellowish $\leq 24.70\%$
4	About 25%	$24.70\% <$ yellowish $\leq 39.40\%$
5	About 50%	$39.40\% <$ yellowish $\leq 58.00\%$
6	More than 75%	$58.00\% <$ yellowish $\leq 71.66\%$
7	100%	$71.66\% <$ yellowish $\leq 100\%$

The percentage shares of yellowish scales for each index are presented in Table 2. These 7 indexes of ripeness are grouped into three classes, namely unripe, ripe and fully ripe, based on the score of yellowish percentage and the ripeness level according to index maturity in Table 3.

Table 3
Ripeness level according to the maturity index [1]

Ripeness	Index of maturity
Unripe	index 1, index 2
Ripe	index 3, index 4, index 5
Fully ripe	index 6, index 7

4. Results and Evaluation

An experiment was carried out to improve the accuracy of ripeness classification procedures. 86 sample images of 43 pineapples, including those used in Subsection 3.5, were sent to the SALCRA in order to be graded manually by local experts. Based on the manual grading process, 12 of the samples were classified as unripe, 12 as ripe and 19 as fully ripe. The expert grader's assessment was then compared with the data obtained with the use of the prototype system (Table 4).

It turned out that six pineapple samples had been misclassified. All samples classified manually as fully ripe were misclassified as ripe when using the prototype system. One of the reasons is that some samples have large pineapple eyes, meaning that the diagonal lines took those areas into consideration as well. Also, some pineapple samples are characterized by huge differences in the percentage share of yellowish scale between front and back sides of the fruit (Fig. 14). On top of that, classification inaccuracy may also be caused by poor light conditions prevailing when taking sample images.

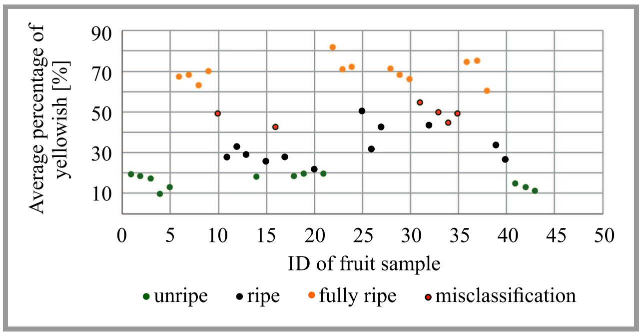

Fig. 14. Results achieved with the use of the proposed solution.

The accuracy of fruit ripeness classification can be calculated as:

$$Classification\ accuracy = \frac{Number\ of\ correct\ classifications}{Number\ of\ experiments\ involving\ fruit\ samples} . \quad (5)$$

The results show that the accuracy rate achieved by the prototype system while classifying an grading pineapples equals 86.05%.

Table 4
Results achieved by the prototype system and manual grading

Sample number	Percentage of yellowish (front image) [%]	Percentage of yellowish samples (back image) [%]	Average percentage of yellowish samples (whole fruit) [%]	Ripeness category (manual grading)	Ripeness category (automated grading – prototype system)
1	17.74	20.31	19.02	U	OK
2	17.99	18.01	18.00	U	OK
3	23.78	9.57	16.68	U	OK
4	9.79	8.46	9.13	U	OK
5	9.92	15.15	12.49	U	OK
6	71.72	62.60	67.16	FR	OK
7	72.94	62.90	67.92	FR	OK
8	59.12	66.65	62.89	FR	OK
9	62.73	76.05	69.39	FR	OK
10	47.51	49.96	48.73	FR	M
11	25.93	29.08	27.51	R	OK
12	40.15	24.71	32.43	R	OK
13	31.67	25.30	28.49	R	OK
14	15.22	19.86	17.54	U	OK
15	27.43	23.17	25.30	R	OK
16	43.48	41.00	42.24	FR	M
17	31.60	23.15	27.37	R	OK
18	18.38	18.00	18.19	U	OK
19	17.58	21.51	19.55	U	OK
20	23.18	20.19	21.68	R	OK
21	23.68	14.78	19.23	U	OK
22	82.39	80.59	81.49	FR	OK
23	72.54	67.90	70.22	FR	OK
24	66.73	77.04	71.88	FR	OK
25	54.90	45.70	50.30	R	OK
26	33.88	28.90	31.39	R	OK
27	36.19	48.28	42.24	R	OK
28	69.38	72.18	70.78	FR	OK
29	63.28	72.79	68.04	FR	OK
30	62.44	68.86	65.65	FR	OK
31	55.42	53.10	54.26	FR	M
32	39.52	46.40	42.96	R	OK
33	41.43	57.39	49.41	FR	M
34	55.03	33.94	44.49	FR	M
35	47.43	50.65	49.04	FR	M
36	72.83	75.95	74.39	FR	OK
37	71.66	77.24	74.45	FR	OK
38	61.76	58.01	59.89	FR	OK
39	29.37	37.27	33.32	R	OK
40	27.46	24.99	26.23	R	OK
41	14.54	14.51	14.52	U	OK
42	16.79	8.81	12.80	U	OK
43	14.04	7.61	10.82	U	OK
FR – fully ripe, U – unripe, R – ripe, M – misclassified					

5. Conclusions

In this paper, the proposed algorithms are used to classify the ripeness and to improve the accuracy of the process of grading pineapples. The system's algorithms are capable of classifying pineapple samples into three main groups, namely unripe, ripe and fully ripe. The overall accuracy rate achieved equaled 86.05%.

One of the limitations is that the system relies on two sample images for each classification procedure, showing the front and the back of the fruit. Thus, a specimen with uneven distribution of yellowish scales around its body may be improperly classified based on the average percentage share of yellowish scales.

In addition, the image of the sample must be captured in a controlled environment. Images taken in differing circumstances affect the end result as well. The positions of six diagonal lines are currently fixed, meaning they may intersect with the eye of the pineapple. The prototype system is also operating offline.

Future work will consist in capturing more pineapples in the same sample and in adding images of a larger number of sides of the fruit (the current prototype system is limited to two sides per sample) in order to achieve higher efficiency and accuracy of the classification process. Furthermore, the system may be improved to estimate the weight and the species of pineapples based on their size and shape.

Many improvements are still needed in order to enhance the operation of the system prior to its real-life application. The prototype system may only be operated under certain controlled conditions. All of its limitations must be addressed in the course of the work to be performed in the future.

Acknowledgements

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