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Grading and Sorting of Carabao Mangoes using Probabilistic Neural Network

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Abstract. This study is about grading and sorting mangoes based on their physical appearance and size using image processing and probabilistic neural network. It focuses on classifying extra class mangoes according to small-, medium-, and large-sized. An Arduino microcontroller connected to a PC is used to control the sensors, DC motor, and Servo motors. The mangoes are loaded into the mango tray and one mango at a time is allowed to move on the conveyor. Once inside the system, an image of the mango is captured and pre-processed. The image is segmented to isolate the mango from the background, a greyscale transformation is applied afterwards. The image is then converted into binary to remove color invariances. The area, color, and black spots area are extracted, which are then sent as inputs to the neural network that grades the mango based on the data acquired. Once the mango has been graded, flaps along the conveyor direct the mango towards its proper classification. T-test was used to verify the use of area as the basis for the size of the mango. 87.5% accuracy was obtained after applying confusion matrix to verify the accuracy of the proposed system.

INTRODUCTION

Mango is one of the major fruits that are exported by the Philippines. It is the third most exported crop by the country in terms of export volume according to the department of agriculture [1]. One of the most popular varieties of mangoes that are grown here is the Carabao Mango or also called the Philippine Super Mango and it is considered as one of the best variety of mango in the world [1]. A major factor that affects mango exportation is the sorting and grading procedures after harvest. Categorization is the procedure of classifying the mangos into distinctive groups based on their diversities. Grading is the process of classification based on the quality [2]. Grading is significant commercially because a quality-grade fruit fetching higher price and demand in the market [3]. In addition, the overall external appearance the mango fruit determines the purchasing decision of a customer [4].

Several studies have reported on evaluating the quality of the mango based on the external appearance using fuzzy logic image processing [5], feature extraction using Mandami-fuzzy [6], parametric visual analysis [7]. To acquire and analyse an image, machine vision technology is utilized to obtain information of an object [8]. Pattern recognition techniques such as neural network, or fuzzy logic can be used with machine vision to design a sorting system for fruits [9-11]. The previous study has classified mangoes successfully using machine vision and image analysis.

Thus in this study, a system was created that would allow extraction of mango's physical features and use it to classify the mango depending on its size and class. Artificial neural networks were used in creating a classification method that would be able to differentiate extra class mangoes into three size categories. The study will be focusing on the Carabao Mango variety that is most commonly grown here in the Philippines and exported abroad.

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METHODOLOGY

The conceptual framework is shown in Fig. 1. A mango sample is acquired using a camera. Then the Then the image is pre-processing for feature extraction. The next stage is the process where feature extraction is where the features of the mango are extracted. There are three characteristics that are extracted from the image which are area, color and black spots. The area is measured by the total black pixels from the binary image. Color is measured by calculating the mean RGB value of the image. Black spots are measured by implementing edge detection to detect the black spots on the mango. The last step is the grading of the mango which will be graded using probabilistic neural network. All the data extracted from the image is used as input into the PNN which then classifies the mango into one of the extra class size categories or others.

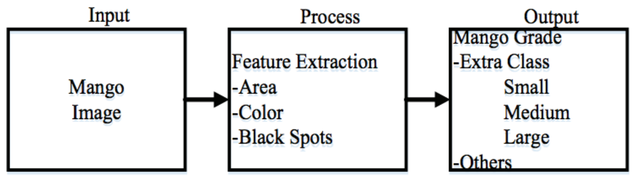

FIGURE 1. Conceptual Framework

The block diagram of the system is shown in Fig. 2. The camera, flaps, and conveyor dc motor are connected to the microcontroller to synchronize the process. The microcontroller sends a signal to the computer whenever a mango is ready for image capture using the USB connection. The computer captures and processes the image with the software installed on the system. The lighting, computer, and conveyor are connected to the main power outlet.

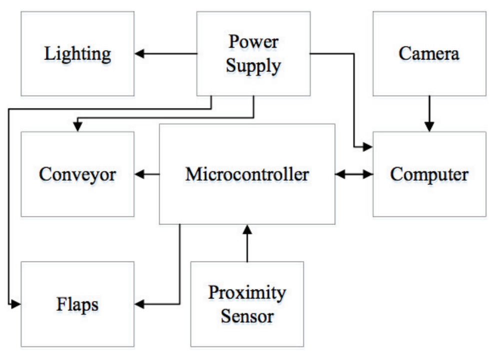

FIGURE 2. Block diagram of the system

The system will function as shown in Fig. 3. First, the system starts the conveyor and continuously checks if a mango detected. If a mango is detected, the conveyor stops and an image of the mango to be graded is captured. The image is preprocessed for the next step and features are extracted. The values are then compared to the existing dataset for grading and the result is showed to the user. The image preprocessing includes segmentation and grayscale. First, the image is converted to YCbCr color space and the color range of the mango is filtered. After the filtering, the image is returned to the RGB color space. A copy of the segmented image is created and converted to grayscale to be used for the next process. The feature extracted are area, black spots and RGB values. It begins by converting the grayscale image to binary image to easily compute the area. Next is the application of the Sobel edge detection on the grayscale image followed by conversion of the image to binary in order to detect the black spots of the mango. The last feature that is extracted is RGB values, where the value of each pixel of the mango is added and then divided by the total mango area to attain the average value of the Red, Green and Blue pixels. The process result starts with the comparing of the extracted features to the existing dataset to get the result. Next is the start of the conveyor then the movement of the flaps. Probabilistic neural network is used to classify the grade of the mango. After the images are processed, it will now enter the PNN processing where the data gathered are compared to the dataset to accurately classify each of the samples. The input to the PNN is the characteristics of the mango sample.

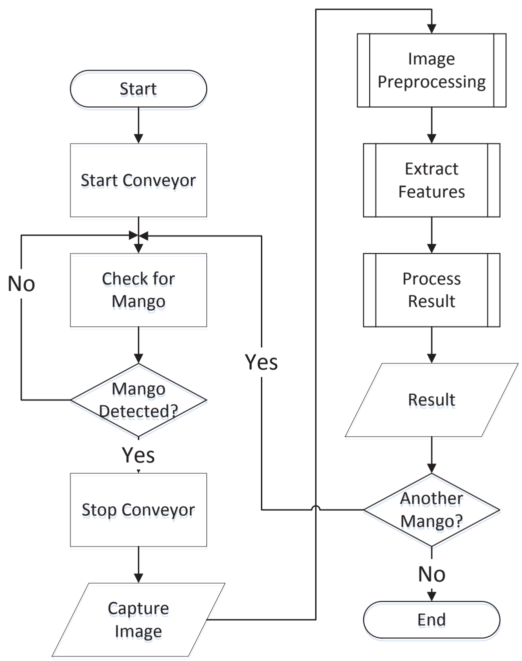

FIGURE 3. System Flowchart

RESULT AND DISCUSSION

The mangoes are weighed before starting the training process to correlate the weight with the mangoes size. The weight of the mango is divided by the area to get the weight per pixel value. The mean value is calculated after all of the samples are processed. The mean value of weight per pixel is calculated using the equation 1. 30 samples were used to get the mean weight per pixel of the mangoes and the other half is to be used to verify the validity of the method.

$$M = \frac{\Sigma\,\mathrm{mg}}{\Sigma\,\mathrm{pix}} \tag{1}$$

Where Σmg is the summation of the weight of the mango, and Σpix is the summation of pixels of the mango. The weight is divided to the pixels to get the 6.87mg/pix. To get the weight of the mangoes based on pixels, the equation 2 is used. Where W is the computed weight and the P is the area of the samples.

$$\mathrm{W} + \mathrm{M} = \mathrm{P} \tag{2}$$

The comparison results between measured and computed weight is shown in Table 1. The expected values for the area must fall within 31994 to 36221 pixels for the mango to be classified as a small. For medium sized mangoes the values for the area must fall within 37226 to 40528 pixels. Large mangoes are expected to have an area of 40466-49002 pixels.

TABLE 1. Measured vs Computed Weight

Sample	Area (Pixels)	Measured Weight (g)	Computed Weight (g)
Small 1	35389	229	243.24
Small 2	34652	227	238.18
Small 3	34796	225	239.17
Small 4	32058	204	220.35
Small 5	33636	209	231.19
Small 6	33892	225	232.95
Small 7	35375	231	243.15
Small 8	32223	205	221.48
Small 9	34238	236	235.33
Small 10	36221	231	248.96
Medium 1	37852	257	260.17
Medium 2	40528	272	278.57
Medium 3	37558	267	258.15
Medium 4	40073	270	275.44
Medium 5	40428	270	277.88
Medium 6	39337	260	270.38
Medium 7	39782	276	273.44
Medium 8	39906	276	274.29
Medium 9	39087	280	268.66
Medium 10	39016	267	268.17
Large 1	44640	314	306.83
Large 2	44963	314	309.05
Large 3	49002	368	336.81
Large 4	42810	302	294.25
Large 5	48173	347	331.11
Large 6	47900	347	329.24
Large 7	45806	329	314.84
Large 8	45546	329	313.06
Large 9	46936	335	322.61
Large 10	42600	301	292.81

The study deals with only a small number of samples. T test was used to verify the acceptability of the method. Two-tailed T test was used for verification since it is applicable when the number of samples is equal. There are 120 samples in total, 30 for each variant. 20 samples for each class are used for training. The researchers only used a total 40 samples in testing, 10 for each extra class size category. The hypothesis to be tested is whether the area of the mango can be used to verify the size of the mango. For the testing, the weight is the basis on the significant difference.

- H0 → There is no significant difference between the measured weight and computed weight.
- H1 → There is a significant difference between the measured weight and computed weight.

The condition to accept the null hypothesis (H0) is that the t-computed is between the two t-critical values.

Using Two-tailed T-Test based on Table II, the t computed -0.3214 is in between the critical value -2.0017 and 2.0017, the researchers accepted the null hypothesis (H0) that there is no significant difference between measured weight and calculated weight.

A Confusion Matrix was used to describe the performance and accuracy of our system on a set of test data for which the true values are given. The number of mangoes will be given, including the number of mangoes for each size and grade. The accuracy of 87.5% is calculated based on Table 2 using equation 3.

$$Accuracy = \frac{a + b + c + d}{\sum samples} x\ 100 \tag{3}$$

As seen in the Table 2, 10 samples are used for each mango size and for the Others category. The system performs well in the Large category while also displaying a good accuracy for the small and medium sizes. It is observable that the system is having trouble in identifying other categories of mangoes as it had less accuracy compared to the other categories.

TABLE 2. Confusion Matrix

		Predicted			
		Small	**Medium**	**Large**	**Others**
Actual	**Small**	9 (a)	0	0	1
	Medium	0	9 (b)	0	1
	Large	0	0	10 (c)	0
	Others	1	0	2	7 (d)

CONCLUSION

The results showed that the study graded and sorted mangoes depending on their size and class. The device extracted the mango's physical features through image processing and each mango is graded through the use of probabilistic neural network. The weight of the mangoes was approximated using the total pixel size of the image of the mango. Acceptability of the method was validated using a two tailed T-Test. The probabilistic neural network detected the extra class mangoes and classified it into three size categories namely small, medium, and large. Mangoes are placed into the ramp and only one mango at a time is allowed to move along the conveyor once the device is started. The accuracy of the system was 87.5% computed using confusion matrix. Through the use of flaps, mangoes are directed to their proper container after classification.

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