

Mango Classification System Based on Machine Vision and Artificial Intelligence

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Abstract—Sorting and Classification of mango, there are different colors, weights, sizes, shapes and densities. Currently, classification based on the above features is being carried out mainly by manuals due to farmers' awareness of low accuracy, high costs, health effects and high costs, costly economically inferior. The internal quality of the mango such as sweetness, hardness, age, brittleness... is very important but is only estimated by external or human-perceived evaluation. Therefore, it is necessary to use artificial neural networks to solve this problem. This study was conducted on three main commercial mango species of Vietnam to find out the method of classification of mango with the best quality and accuracy. World studies of mango classification according to color, size, volume and almost done in the laboratory but not yet applied in practice. The quality assessment of mango fruit has not been resolved. Application of image processing technology, computer vision combined with artificial intelligence in the problem of mango classification or poor quality. The goal of the study is to create a system that can classify mangoes in terms of color, volume, size, shape and fruit density. The classification system using image processing incorporates artificial intelligence including the use of CCD cameras, C language programming, computer vision and artificial neural networks. The system uses the captured mango image, processing the split layer to determine the mass, volume and defect on the mango fruit surface. Especially, determine the density of mangoes related to its maturity and sweetness and determine the percentage of mango defects to determine the quality of mangoes for export and domestic or recycled mangoes.

Keywords-the classification of mango; sorting of mangoes; image processing technology; artificial intelligence; computer vision; artificial neural networks.

I. INTRODUCTION

The process of grading mango in Vietnam and the world is being carried out mainly by the direct labor of farmers. In the process of surveying and assessing some agricultural

classification systems, the mango classification system on the market is not available in Vietnam. So achieving low productivity, increasing costs. Surveying some of the currently used automatic or semi-automatic agricultural classification systems can be designed and made into a mango classification system. Research and application of high-tech machinery in the process of producing agricultural products on the one hand reduce human labor, reduce costs, and otherwise meet high standards of food safety and hygiene in Processing in fastidious markets requires high quality.

The proportion of fruit is considered as a mature indicator of mango fruit. The ripe fruit is submerged in the water while the fruit is alive. Fruit with density greater than 1.00 are submerged in water due to high content of dry matter in the fruit, while fruits with density less than 1.00 are floating in the water.

$$\text{The fruit size index} = (\text{wide} * \text{thick}) / \text{long}$$

on Cat Hoa Loc mango (Vietnam) is strongly correlated with fruit density. Similarly, fruit density, dry matter weight and sugar content are correlated but not correlated with neutralizing acid. Analysis of quality criteria: Brix, dry weight, sugar content, starch content of live fruit, hardness measurement, density, color, fruit weight, sugar content, pH of fruit flesh to determine determine the best quality of mango.

Mango is a very sensitive agricultural product and can easily appear brown spots after being crushed during post-harvest handling, transportation and marketing. Testing of the fruit of this fruit used today cannot detect lesions at an early stage of adulthood and so far no automated tools are able to detect; studying the approaches and techniques to assess the quality of mango fruit, checking the surface of mango fruit with deep, wilting, spongy, deformed mangoes, ripening on mango fruit; application of image processing technology, computer vision combined with artificial

intelligence in the problem of classifying mango fruit with or without quality.

Currently mangoes are classified by color, volume, size and shape. The quality of the mango fruit is only predicted by the eye of the classification and has not been studied for application. Case studies of mango classification such as Machine vision-based maturity prediction system for harvested mango classification [1] proposed a machine-based system to classify mangoes by predicting levels maturity to replace manual classification system. Prediction of ripeness was made from video signals collected by a CCD camera placed above the mango conveyor belt. The recursive feature removal technique combined with the support-vector machine (SVM) classifier is used to identify the most relevant features of the original 27 selected features. Finally, optimal aggregation of the number of reduced features is obtained and used to classify mangoes into four different types according to maturity level; Tomas U. Ganiron Jr developed a size-based mango classification system using image analysis techniques [2]. This empirical study aims to develop an efficient algorithm to detect and classify mangoes. Using the obtained image, the features of the mango are extracted and used to determine the mango layer. The characteristics of the extracted mango are perimeter, area, roundness and defect rate; The mango classification system uses machine vision and Neural network [3] as a system that can classify ripe or unripe mangoes. The method used to carry out this study was split into several steps: object identification, algorithm development, implementation and evaluation. This system is implemented in C, Computer Vision and ANN (artificial neural networks) so that the system can detect the color of the ripe or unripe mangoes; The research team in Malaysia [4] proposed and implemented fuzzy logic algorithms and algorithms using digital image processing, predefined content analysis and statistical analysis to determine real estate export of local mangoes in Perlis - Malaysia. This study is to design and develop an efficient algorithm to detect and classify mangoes at 80% accuracy compared to human classification. All studies are mostly done in laboratories, with certain results in the exploitation of specific classification features, with a high classification result in color, volume and size. However, the quality of the mango has not been assessed, but it has been put into practical applications. The studies [5 - 12] mentioned the application of image processing and artificial neural networks with different treatments for fruits, vegetables, fruits and other foods and for certain results in research assist.

The study, design and manufacture of mango classification system to control and evaluate the quality of mango fruit (according to GAP standards) before being packaged and exported to the market: mangoes are harvested at the right level. ripening, size, shape, eliminating fruits withered, deep, deformed. More specifically, "the application of computer vision and image processing technology combined with artificial intelligence to identify patterns and evaluate the quality of mango fruits" in order to enhance automation in agricultural production in our country.

II. METHODS AND TECHNIQUES USED TO STUDY

Apart from the characteristic color, weight, size, shape and bruises damaged to determine mango quality, the most important factor to determine mango quality is the proportion of mangoes. The proportion of mangoes is also understood as the maturity or age of mangoes, it is related to the date of harvest of mangoes. According to international standards, currently the proportion of mangoes ranging from 1.0 to 1.1 is the best quality mango. And currently this factor has not been studied because it is difficult to handle mangoes to determine the density, so this study will be mentioned to solve this problem.

The shooting process involves capturing a color image (RGB) and performing a depth measurement (D), which is combined in different ways to form other colors on a pixel, the intensity of Each color can vary from 0 to 255 and produce 16,777,216 different colors. Image sensors combined with depth sensors are located close to each other, allowing merging maps, producing 3D images. RGB-D image information is stored. The study was conducted through the following steps:

1) Identify research issues from the actual situation, survey how to classify mangoes at home and abroad. An overview of domestic and foreign studies, understanding the existing mango classification systems as well as a survey of the design and design of mango classification system.

2) Learn the local mango assessment and classification criteria. Develop classification methods, arrange classification stages accordingly based on actual surveys. Conduct an analysis of appropriate options, less error-prone methods and best results. Design classification model to meet the required objectives set.

3) Build algorithms, calculation methods so that the error is the lowest and the efficiency is the highest. Begin implementation of local design, manufacturing, empirical evaluation and testing.

III. VISION MACHINE FOR SORTING MANGOES

The mango classification system will handle features such as color, volume, size, shape, defects and especially the density of mangoes. When determining mango volume with Loadcell sensor, mangoes will be taken with 2 cameras in the shooting chamber with the appropriate light intensity from the light bulb. The shooting angles of the mango are random so that the mango fruit image is completely visible. The design of the mango conveyor belt must match the camera's shooting angles because otherwise the image will not take the mango position and process the image to classify the bruises as inaccurate. When conducting experiments, the first task is to design a mango classification model that includes components and operational structures based on the theory and principles of operation of each section and the combination of the distribution system species. The operation system is integrated to handle each stage and combination of stages to handle color, volume, size, shape, density and percentage of defects (Figure 1). The system to be built must include:

- 1) System with shooting chamber to process color images, find shape defects and calculate mango volume.
- 2) Loadcell system to calculate the weight of each mango.
- 3) The system has a wiper mechanism that eliminates unsatisfactory fruits, size, shape.
- 4) The system has a classification mechanism used to classify quality of mangoes into trade items.

Building the principle of operation of mango classification model using artificial intelligence: Conveyed mango fruit brought to the conveyor mounted on the conveyor. In the shooting chamber, there are two cameras for color image processing to find defects on the mango fruit surface such as: black spots, bruises, bruises, and shape defects such as waist, damaged broken, the fruit does not meet the color requirements, the shape will be eliminated, and the camera will also scan the mango fruit (length, width, height) to calculate the volume of the mango. After that, the mango fruit, which meets the requirements of color shape, will be taken to the second conveyor to conduct mass calculations. First, the harvested mangoes are cleaned by using a washing solution, then sorted and sorted into commercial mangoes of different types, this is the current stage sorted by hand. Finally, the mangoes of each classification are packaged and transferred to customers.

A. Inspection Process

First, two images of front and back surfaces are acquired using two cameras. Second, check areas of the mango are found using segmentation modules, each specialised in detecting a different type of feature. Third, post processing is performed to remove false objects and combine areas that represents the same feature. Fourth, both object features and window features are extracted from each located area. Fifth, the features are passed to the neural networks and the outputs of these networks are then combined using the feature combination strategy to assign an overall class to each region. Finally, the mango is graded, using a set of rules, based on the feature type of each located region. An example of a grading table is shown in Table 1. The table shows for each grade, the number, type and size of defects that are permissible.

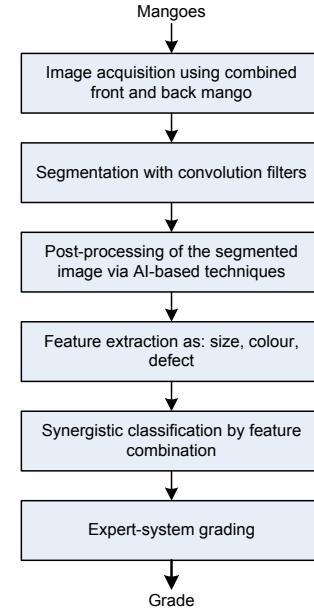


Figure 1. Mango sorting process and developed system for mango grading.

TABLE I. THE MANGO IS GRADED FOR EACH GRADE, THE NUMBER, TYPE AND SIZE OF DEFECTS THAT ARE PERMISSIBLE

Size code	Standard range	Permission range (< 10 % each/package)	Error
A	From 200 to 350	From 180 to 425	112,5
B	From 351 to 550	From 251 to 650	150
C	From 551 to 800	From 426 to 925	187,5

This table can be easily converted into a rule-based expert system. For better results, fuzzy rules can be employed to emulate expert human graders more closely. The segmentation method adopted is based on standard image-processing functions and consists of three stages. Before segmentation, two images of the two surfaces being inspected is acquired using the image from above and beneath the mango. These images contain some features caused by classifications.

The mangoes are rarely perfect spheres, most mangoes are either long ($D < L$). A simple way to account for variation in mango shape is to use the ratio (R) of length to diameter: $R = L/D$. Corrected mango volume will, therefore, have the following equation [5]:

$$V_p = V_s + V_s (KR - 1) \quad (1)$$

Where V_p is the corrected mango volume, and K is a shape factor that varies with fruit type. After development and rearrangement of Eq. 1, the following equation is obtained:

$$V_p = 1.1D^2L\pi/6 \quad (2)$$

With D and L in cm and V_p in cm^3 .

All of the shape features apart from area are invariant to size, since they are measured from profile images normalised to unit area. Since none of the shape features shows any significant correlation with volume (as opposed to K), and since the effects of projection are small, any set of features from a profile image of a corresponding mango can be easily mapped to a new set of features corresponding to the same piece.

IV. USING NEURAL NETWORK TO PREDICT THE BRIX LEVEL OF MANGOES

Neural network is an algorithm that tries to mimic the brain which is a state of the art technique for many applications. After researching and examining on approximately 1000 mangoes (Table 2), we record and summarize all of the necessary values which can significantly affect on the sweet level of the mangoes (brix level). Brix level is the percentage of solids present in the juice of a plant. These solids are mostly made up of sugar and minerals.

It is significant to use Principle component analysis (PCA) to decrease the dimension of the input from 4-dimension to 1-dimension so that we can easily plot the data for visualization. The new feature is called X_PCA (Figure 2).

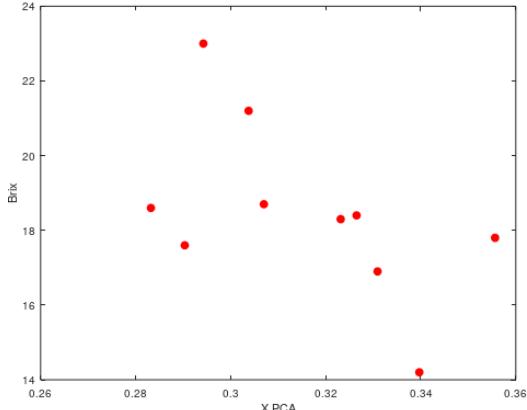


Figure 2. Brix level depends on X PCA (mass, length, width and volume).

All of the factors affecting to the sweet level which can be considered as inputs of our neural network model such as mass, length, width and volume. It is also the first step in building a neural network: choosing the number of input units which should be 5 in this network.

The output will be the brix level (a raw number) which means it is the regression problem so the number of output unit is one. Besides, ReLU functions are applied for hidden layers and the final layer is linear because it is a regression problem.

Number of hidden layers is also the important problem in neural network. We varies the number of hidden layers and the number of units in hidden layers to find the most optimal value of the cost function. There is a recommendation that it should have the same number of units in every hidden layer. Randomly initiating the weights is required instead of zeros

or ones vector like in linear regression or logistic regression initialization. Zeros or ones vector initialization can cause the unexpected equal in values of all units in hidden layers. An for random initialization of a 10×6 matrix is using the epsilon value. θ_{init} is the 10×6 random matrix.

$$\delta\theta = \theta * (2 * \varepsilon) - \varepsilon \quad (3)$$

The next step is implementing the forward propagation to get to $h_{\theta}(x^{(i)})$ for any $x^{(i)}$. Then implement the cost function to see the error value (Figure 3).

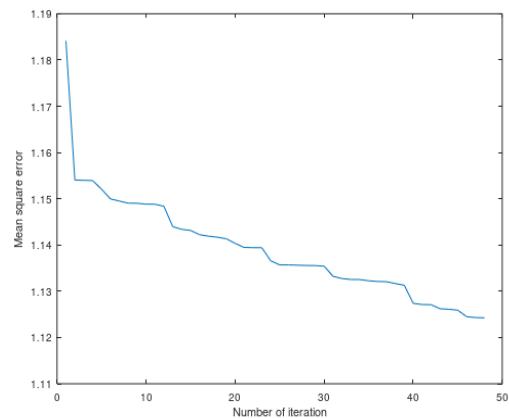


Figure 3. Cost function value per iteration.

After that, implement the back propagation to compute the partial derivatives and use the method which is called gradient checking in order to confirm that the back propagation is running well.

$$\frac{\delta}{\delta\theta} \approx \frac{J(\theta + \varepsilon) - J(\theta - \varepsilon)}{2\varepsilon} \quad (4)$$

Finally, using the Adam optimizer and learning rate decay to minimize the cost function with the weights in theta. After tuning on training set and validation set to evaluate and find the optimal model, a network with 1 hidden layer with 10 nodes (Figure 4) is selected because of optimizing the speed and lowering the value of cost function.

The optimal neural network can predict the brix level of every mango based on its mass, length, width, volume with 98% accuracy on test set.

V. EXPERIMENTS AND DISCUSSIONS

Volume of mango using Camera – RGB:

Find size via Camera: Photos obtained from cameras are RGB color images we need to convert to gray images to manipulate more easily. In the model using additional shooting chamber to increase the ability to receive images and separate fruits more easily (Table 2).

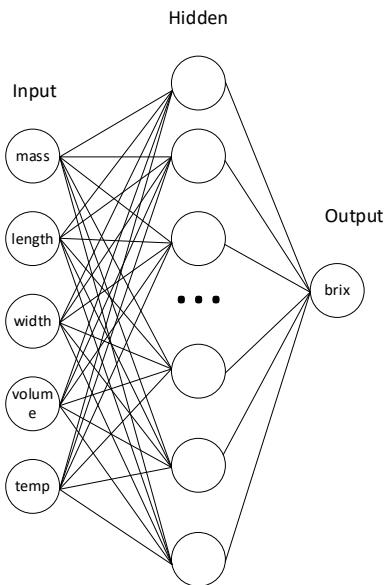


Figure 4. An optimal neural network for predicting mangoes brix level.

First we know that in most mangoes there will be a certain color threshold. So we will adjust the threshold and begin to turn gray image so that the resulting image has background and mango are 2 separate color values. Here the topic threshold is set at 135, the threshold of mango ranges



Figure 5. Results obtained after determining mango size.

The result of mango volume is obtained by calculating statistical method by size using RGB Camera: Above Loadcell is arranged with an infrared sensor to detect objects. When the mango fruit goes to the sensor to return the signal to Visual, at the same time, the bottom Loadcell also weighs the value of the mango at 10ms.

The result is taken into Excel to calculate, we see the relationship between the two original mass quantities and the weight on the conveyor have linear relationship with the first equation (Figure 6):

$$y = a \cdot x + b$$

In which: y is the volume of mango fruit to be calculated
 x is the weight of the weight when weighing the conveyor

a, b is the coefficient

coefficients a and b are determined by SLOPE functions (find coefficient a), INTERCEPT (find coefficient b). Order to determine:

from 140-255. When we have the pixel size and also the size of the pixel, we just need to multiply it, we get the real size of the mango (Figure 5). Calculating mango volume: We rely on the dependent equation found in the method and the actual size found. Replace the equation to calculate the corresponding volume.

TABLE II. THE ERROR TABLE BETWEEN THE WEIGHT OF MANGOES CALCULATED BY THE EQUATION AND THE ACTUAL VOLUME

Order number	Actual volume	Volume calculated by equation	Error
1	410.4543	412.6726	-2.21827
2	469.9725	469.1009	0.8716
3	323.1496	321.4804	1.6692
4	551.0186	550.2169	0.8017
5	442.9044	441.2227	1.6817
6	432.1404	432.4907	-0.3507
7	451.4862	453.1468	-1.6604
8	399.6903	398.9014	0.7889
9	393.7589	395.3746	-1.6153
10	469.9725	469.9407	0.0318

$a = \text{SLOPE } (y \text{ values, } x \text{ values}) = 1.060952497$
 $b = \text{INTERCEPT } (y \text{ values, } x \text{ values}) = 63.01837755$
The equation to look for: $y = 1,060952497 \cdot x + 63,01837755$ (5)

From the newly found equation, we build the block in the PLC to calculate the exact volume. We have wrong results (Table 3):

Average error of acceptable errors: Reasonable equation.

In particular, when determining the mass, volume and density of computation compared to the original elements of mango and comparison chart, we get quite stable and acceptable results Figure 8 (units of dimension of mango are mm, volume is ml).

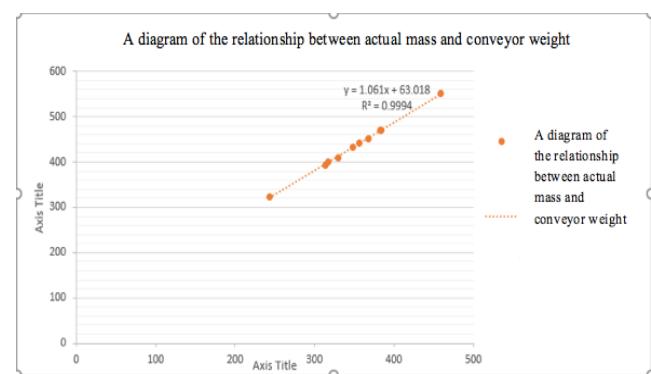


Figure 6. Chart of relationship between actual weight and conveyor weight.

First experiment on mangoes with actual results as follows:

First, convert RGB color image to gray level image: RGB color model, using additional models in which red, green and blue light are combined together in many different ways to form other colors on a pixel, the intensity of each color can change from 0 to 255 and create 16,777,216 different colors. To convert RGB images to grayscale images using functions in OpenCvSharp: Cv2.cvtColor (); (Figure 7a).

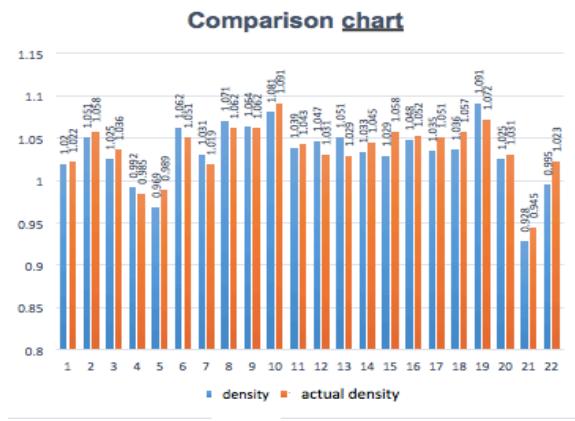
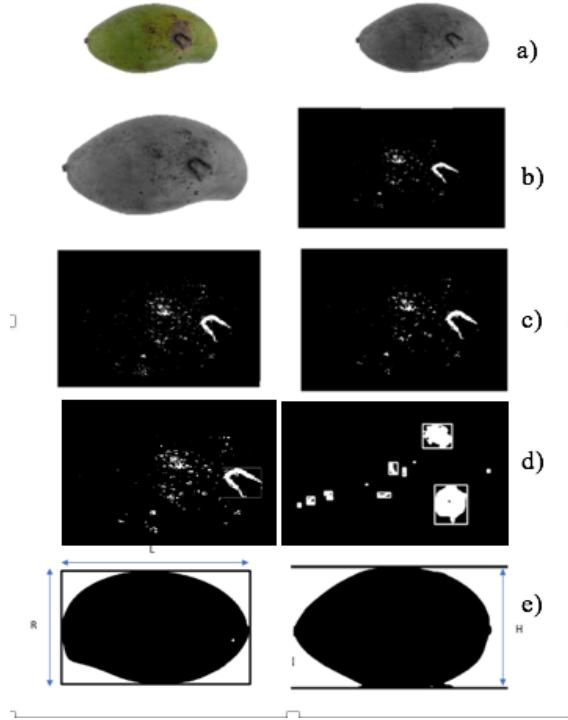


Figure 8. Chart comparison between volume, density calculations than the real factors.

Here the input variable is the size of the mango and the output variable will be the corresponding mango volume (Table 3). The result is:

TABLE III. TABLE OF DEPENDENT EQUATION PARAMETERS (SNAPSHOT)

Figure 7. Image processing process to calculate mango volume.

Image segmentation: Image binary is the process of converting gray images into binary images. Binary images are images where the values of pixels are represented only by two values: 0 (Black) and 255 (White) (Figure 7b).

Detection of defects and calculation of defect areas: Contour algorithm: Contour is the algorithm used in image processing to separate, extract objects, enabling the following processing to be accurate (Figure 7c).

Classification based on area of disability. Calculate approximately the area of a pixel.

Classification: Find the largest area of disability if the disability area is larger or the area of the disability is larger than the area where each disability area has a larger disability area than allowed, mangoes are removed (Figure 7d).

Results of measuring the actual size of a sample mango and the corresponding number of pixels (Figure 7e):

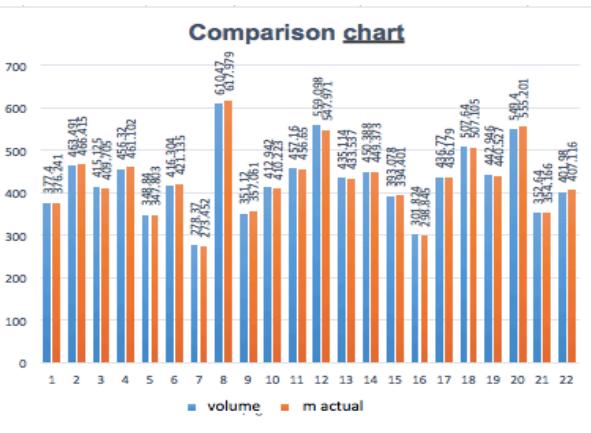
Length (L): 13.69 cm - 426 pixels

Width (R): 8.51 cm - 281 pixels

Height (H): 7.28 cm - 258 pixels

The above word calculates approximately the area of a pixel: $\frac{1369}{4260} \times \frac{851}{281} = 0,09732 \text{ mm}^2$

Determine the area of the mango image obtained from the binary image (borders), determine the length, width and height from this image. Applying formula (1), (2) and Dependency equation between size and volume (5), we deduce the corresponding mango volume.



Model	Coefficients ^a				
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	(Constant)	-1000.959	62.866	-15.922	.000
	Length (mm)	3.249	.352	.452	.000
	Width (mm)	2.956	1.399	.170	.041
	Height (mm)	10.155	1.491	.516	.000

a. Dependent Variable: Volume (ml)

Dependent equation between size and volume:

$$\text{Volume} = 3.249 * \text{length} + 2.956 * \text{width} + 10.155 * \text{height} - 1000.959 \quad (6)$$

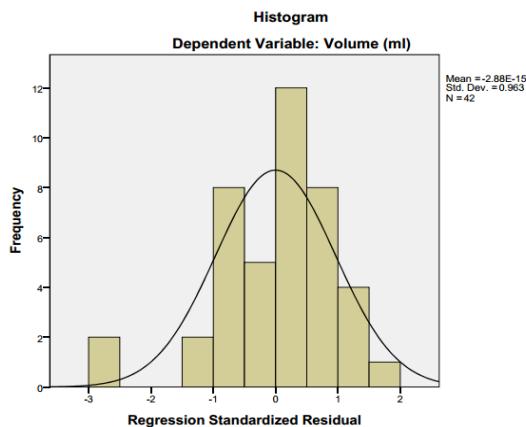


Figure 9. Frequency diagram of the standardization of Histogram.

From Figure 8, we have Mean mean close to 0, the standard deviation is 0.963 close to 1, so it can be said that the remainder distribution is approximately standard. Therefore, it can be concluded that the normal distribution of the remainder is not violated.

And from Figure 9 and figure 10, we see that the distribution points in the distribution of the remainder are concentrated into one diagonal, thus, assuming the normal distribution of the remainder is not violated.

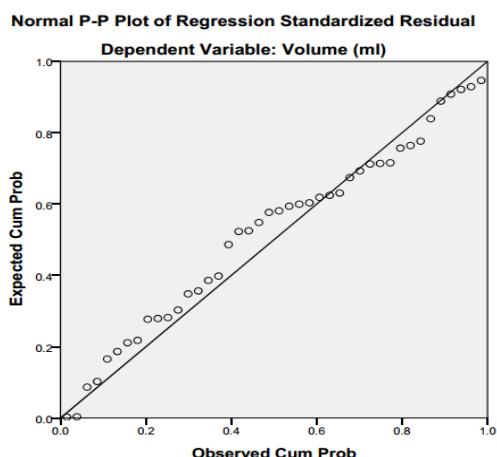


Figure 10. Normal P-P balance diagram.

VI. CONCLUSION

This study described the method and terminology of several of tools that are used for image processing and analysis in sorting and classification of mangoes based on Artificial Intelligence. The digital image processing is required firstly to preprocess the data of mango images into a format from which features can be extracted, and secondly to extract and measure these features.

The fluctuation of mango fruit quality in the market is huge. The best harvesting time for fruit quality depends on many factors including Cat Hoa Loc mango and Cat Chu mango in Vietnam for the best quality when having density from 1.00 -1.02. Fruits are classified by machine vision techniques and artificial intelligence is more uniform in quality than the left harvest by age and market.

The mango images used in this study for sorting and blemish detection are obtained using a CCD camera. Once shape have been extracted from the mango profile images and applied to artificial neural network that is used to combine shape features to form volume estimates for the corresponding mango. The testing method used on ANN and other function approximation methods are explained in this paper.

Eventually, the features are to be combined to form a volume estimate of fruit from whose image they are extracted and measured.

In one of its simplest forms, function approximation is determination of a linear regression equation based on a set of data. This linear relationship is a model for between weight and volume, since one would expect that the volume of mango would be directly proportional to its weight, because mango density is usually almost constant within a same quality. A model must be formed from knowledge of understanding of source of the data. As it is known that mango density increased with the volume, then the quality is better and the mango is sweet (Based on regression equation of weight and volume). ANN can be seen as a form of regression equation which can model arbitrary continuous functions where an explicit model relating the functional form of the output to the inputs is known. The first stage in the computer processing of the digital images from camera is to form separate image files of mangoes. This is necessary since locating the mango within the large image would be very computationally expensive. From these resized images, the grey-scale images are formed from the sum of the red and green bands less twice the blue band. Next, the grey-scale images are threshold to form binary images. The threshold value is simply found based on experiments for each type of mango (with reference to several image histograms). The mango images are calibrated for size by using images of ellipse.

When using artificial intelligence to determine the quality of mangoes including the components of mango fruit, we can classify them without affecting the bad value to the quality of mangoes, related to human health. Solving problems in mango classification system combining computer vision and artificial intelligence will help develop smart mango classification system with commercial scale.

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