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Research Article

Automatic Mango Fruit Classifier Using Image Processing Through Pixel-Based Calculation, Correlation and Logic System

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ABSTRACT

In recent years, automatic vision-based technologies have been used in the sector of agriculture and food industry to achieve better quality of their products. The ability to identify the mango fruit based on its quality yields a greater income for the people in the industry. Manual sorting constitutes problems in achieving reliable and consistent results. An automatic mango fruit classifier based on vision technology is discussed here. The main objective of this study was to develop an automatic mango-fruit sorting machine using image processing through various methods and processes. Moreover, this study was conducted to determine the category of the mango fruit samples as a product and be sorted according to their quality. The study focused on the extraction of its physical qualities (size, color, and spots) using a new set of algorithms, processes, methods and software and developing a new way of sorting products that could help in the agricultural industry. It aimed to simplify existing technologies on grading or classifying products and tested the accuracy of the system by conducting several experiments. The application of the vision system aims to divert the manual inspection of the mango fruit into automatic classification and sorting. To speed up the process of inspection, maintain consistency and achieve reliable results, a system that uses image processing through various methods were used. The extracted qualities of the fruits were combined using program codes on the software. The combined qualities were graded according to an established standard. Additionally, the output was represented by a Graphical – User Interface and a voice prompt. The system achieved an accuracy of 93.33 %

KEYWORDS

Sorting, vision technology, image processing, mango fruit classifier

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INTRODUCTION

The technology has been experiencing a period of growth. It is now becoming more advanced and sophisticated by and by. It has been focusing on making people's lives more innovative and easier. Furthermore, the development of these technologies makes a fast-paced society.

In recent years, automatic vision-based technologies have been used in the sector of agriculture and food industry to achieve better quality of their products. The ability to identify the mango fruit based on its quality yields a greater income for the people in the industry. Manual sorting imposes problems in achieving reliable and consistent results.

The proposed algorithms from the study of Yimyam et al. (2005) were implemented in C/C++ and MATLAB on a typical PC. For image acquisition, a scanner and a 3 – Megapixel digital camera connected to the PC were used. The researchers employed the system to evaluate the physical properties of a mango cultivar called "Nam Dokmai". Sixty mango samples were obtained from a local mango farm in Chachoengsao, a province in central Thailand. The mangoes were harvested at the same maturity as they are harvested for export. There were three various sizes: Small, Medium and Large (twenty mangoes for each size). They were graded by an experienced farmer.

A study in 2013 used an acquired image in RGB format which is a true color format for an image. In MATLAB, the captured or imported RGB image is three dimensional and each pixel is represented by an element of a matrix whose size corresponds to the size of the image. (Rege et al., 2013) In a pre-processing step, the contrast of an image was improved and the blue component from the RGB color space was extracted. The blue component was chosen because it is the most discriminant component to remove the background of the image, due to the fact that for the orange color (made of red and some green), the value of the blue component is zero. (Mercol et al., 1998) The region of interest is the fruit itself without the background. The background is the noise to the image and needed to be removed. The background is set black in the whole process to capture the image. The black background color is easier to extract and it allows the fruit edge characteristics to stand out. (Jadhav and Patil, 2013)

In order to find the boundary or contour of the mango, a graph contour tracking method based on chain-code was adopted by Nandi et al. The algorithm was found to work faster because the boundary of the sample is complex. The algorithm first detects every run at each row and records every single run's serial number. The corresponding start-pixel coordinates and end-pixel coordinates are stored in a table named as "ABS". This method lets the run-length code of the image be gathered. A 3x3 pixel box is acquired to determine the correlation between the objective pixel and its own eight-connected surrounding pixels. A table marked as "COD" is used to record run's serial number with their corresponding class labels. This allows the algorithm search for the "ABS" and "COD" tables sequentially. The starting pixel of the contour is determined and followed based on the coordinators and the recorded classes. (Nandi et al., 2014)

The enumeration of the related pixels after the elimination of background and execution of the defect detection algorithm provides the calculation of the area of the cherry. The cherries were classified into various specific groups to evaluate the accuracy of the algorithm sine classification. The values were converted into pixels. In order to sort the cherries in the unit of square centimeter, the value of area in pixel can be multiplied in a certain number. In this case, sorting is be possible based on physical units. The calculated number for converting pixel to the equivalent square centimeter was 1.25x10^-4. The accuracy for each size gives the large 95%, medium 94.6% and small 96%. (Nandi et al., 2014)

The representation of the maximum diameters projected on the principal axes of the image of the fruit yields the size calculation of the fruit. The principal axes determines the axes of minimum and maximum moment of inertia of the outline of the fruit. This procedure works for round and elongated fruits. During the system configuration, size in pixel unit is transformed to millimeter (through calibration factors and phases). (Sanchiz and Saanchez, 2001)

The colors used for classification are red, green and yellow because the difference between the fruits are emphasized using these colors. The red and green components are calculated by counting the pixel values corresponding to the red and green colors. The yellow component is calculated by converting first the RGB image to CMY (Cyan, Magenta and Yellow) by using the function "imcomplement(RGB)" with the syntax IM2=imcomplement(IM). (Naganur et al., 2012) For color analysis, the researchers segmented the projected image of mango into five (5) regions. Each region was analyzed and the average color (RGB) of the image was recorded. This spatial color information is indexed in the database for future classification. The results showed that the color spatial distribution is not related to its size. (Yimyam et al., 2005)

One kind of fruit is separated from the other set of fruits. Fuzzy logic method is used in the study. The output membership function is anticipated as fuzzy sets by the Mamdani-type inference. A fuzzy set for each output variable (needing deffuzification) is provided after the process of aggregation. (Naganur et al., 2012) Feature matching methods essentially consist of detecting features in images that can be matched with corresponding features in other images from which a transformation model can be estimated. Feature matching is an important task in the area of image processing. In this study, correlation method is used for feature matching. (Kalaivani et al., 2013)

An automatic mango fruit classifier based on vision technology is discussed in this study. The application of the vision system aims to divert the manual inspection of the mango fruit into automatic classification and sorting. To speed up the process of inspection, maintain consistency and achieve reliable results, a system that uses image processing through various methods was used. The automated system uses a web camera to capture the mango samples and import it on the system. Various pre-processing procedures were also implemented in the system to improve the images and make them compatible for the extraction of its features. Different methods and techniques were also brought out to extract the needed features of the mango, specifically the color, size and the texture of the mango. These extracted qualities were combined using program codes on the software. The combined qualities were graded according to their combination. The categories were assigned with a set of unique qualities. Additionally, the output was represented by a Graphical – User Interface and a voice prompt.

The significance of this study was to automate the sorting and grading system of the mango industry and free the workers from manual work. This was achieved by improving and incorporating the system with image processing in sorting and grading mangoes according to their size, color and spots. Additionally, it could open the possibilities for further application of image processing not only in the mango industry but also for other agricultural products. Moreover, this study was conducted to improve the sorting method in the mango industry; presents new sets of methods in the image processing system; provides new combination of existing and new processes in sorting samples especially in the mango fruit industry; supports the improving technology used in the agricultural industry by using developed technological software, algorithms, methods, processes and devices; proves the effectiveness of application of modern technologies in the agricultural industry; and improve the quality of produced mango fruits export-ed in the market by organized sorting. Furthermore, this study was conducted to encourage the farmers and businessmen especially in the mango industry to shift into the modern way of sorting.

METHODOLOGY

This section includes the design, methods, techniques, processes and testing of the system. Figure 1 shows the steps and methods to accomplish the whole system. This is a modified step-by-step designed process to achieve the objectives of the system. This study is a mixed combination of a qualitative and quantitative data analyses. Descriptive data presentations and qualitative data analyses acquired from observations and experimentations were incorporated in the study. In addition, quantitative analyses were also employed.

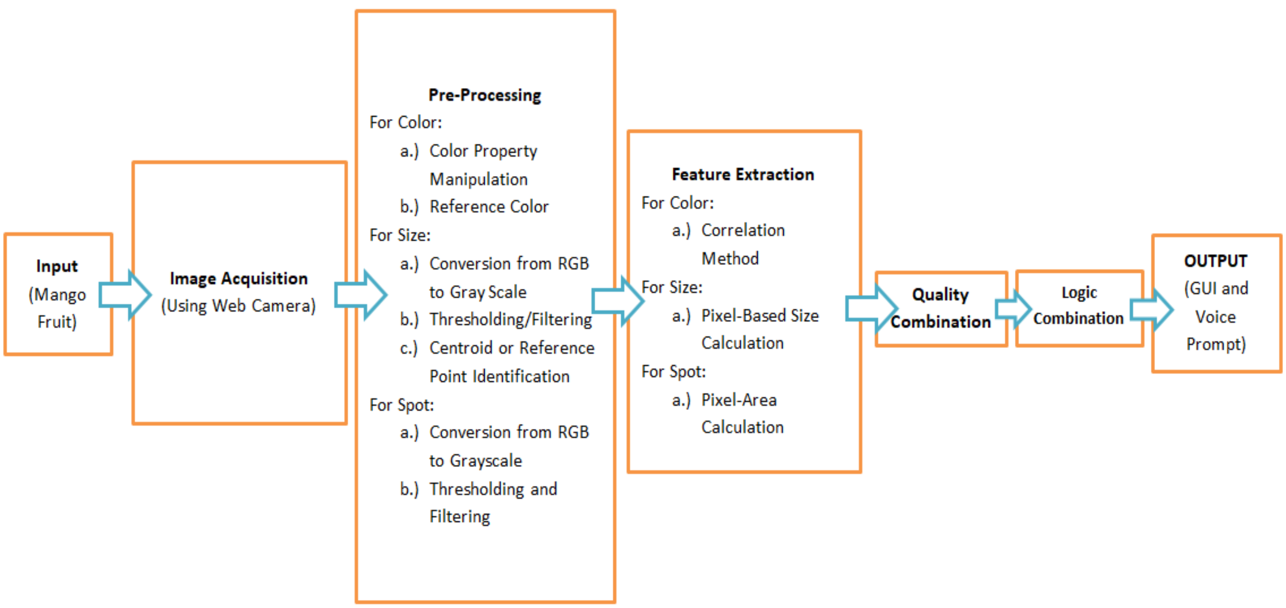


Figure 1. Block Diagram of the System

Figure 1 shows the block diagram for the system of the Automatic Mango Sorting Machine. The input sample is the mango fruit harvested from Pangasinan. The image of the sample was captured using an image acquisition tool in an engineering software. It was transferred to the pre-processing stage where various methods in feature extraction were used. This process improves and highlights the features needed in the next process. The next process is the feature extraction of the three physical qualities of the input. In the said stage, physical qualities were extracted from the sample separately. Different methods were used to extract the size, color and detect the spots of the input image. The extracted qualities were combined in the next stage of processing, the quality combination. The combined qualities were graded based on their category or class in the next stage using a logic system. Categories with a unique set of combined qualities were established where the pre-processed data from the sample could fall into. The last stage was the output where a GUI (Graphical User Interface) and voice prompt were used. A voice prompt was used to audibly indicate its class or category while the GUI presented the output visually and interactively.

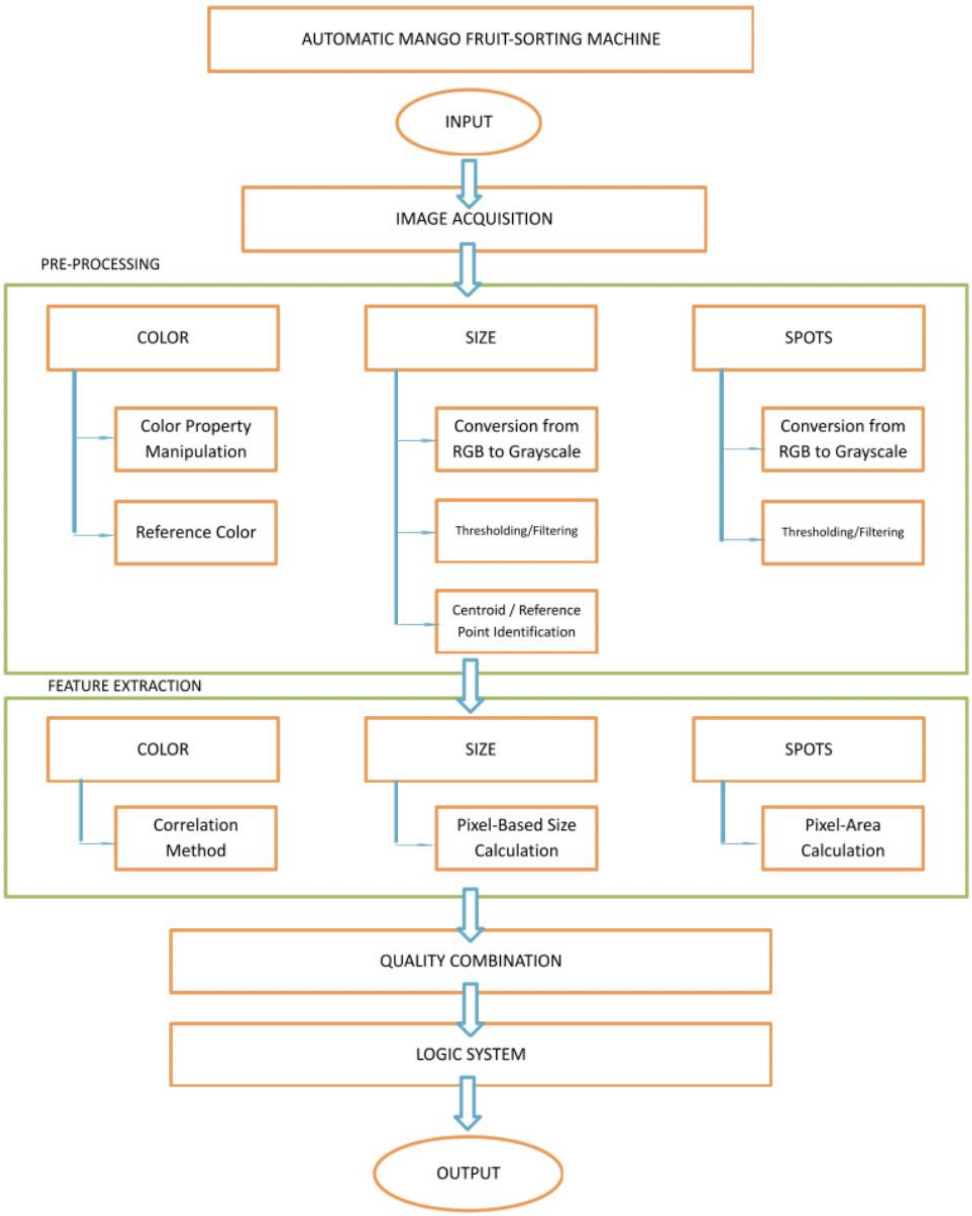


Figure 2. System Flow Chart

The system flow chart in Figure 2 and 3 shows the systematic flow of processes in the whole system. The charts specify the series of actions in the system during an operation.

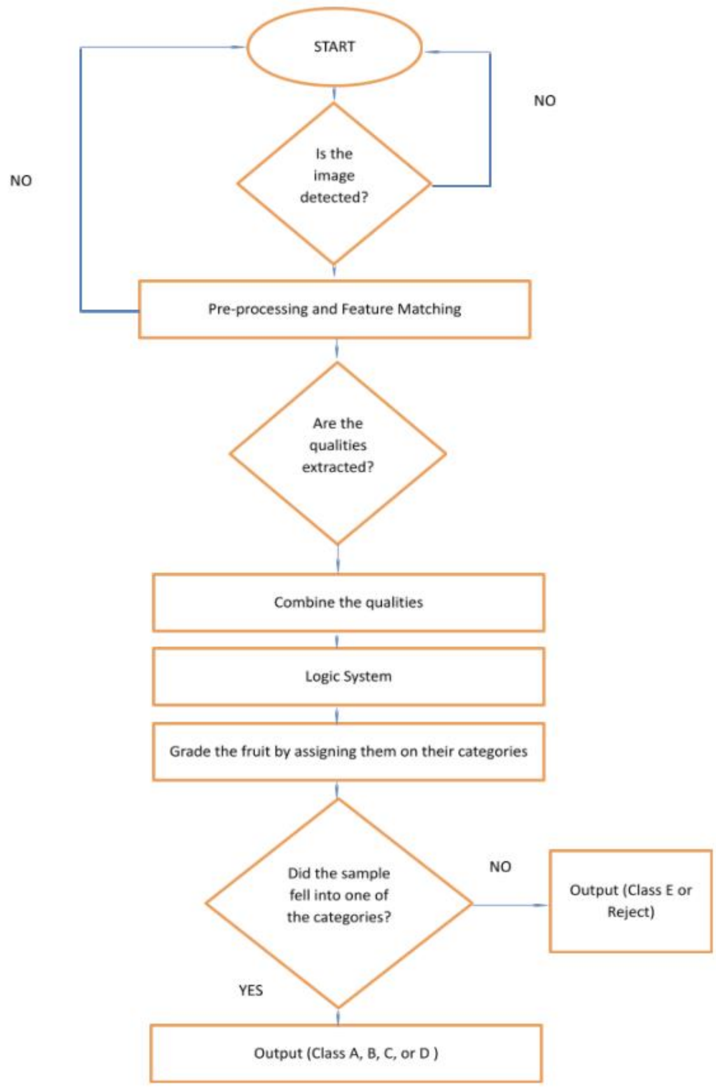


Figure 3. Specified Chart for the System

Input

The mango fruit harvested from the province of Pangasinan, a province in the Philippines, represents the input of the system. The variety of the fruit was only concentrated in the native mango found in the said province. The categories of the input were established by conducting surveys on mango growers and producers in the area. According to the respondents, each category contains a set of unique qualities. The following table shows each category containing qualities.

Category	Qualities
Class A	Large, Green, Spotless
Class B	Medium, Green, Spotless
Class C	Small, Green, Spotless
Class D	Extra Small, Green, Spotless
Class E	Reject

Table 1. Categories of the mango with their corresponding qualities

The above table (Table 1) serves as the basis and guide in the whole process of the system. The table shows the standard categories and their corresponding qualities.

Image Acquisition

Before any video or image processing can commence, an image must be captured by a camera and converted into a manageable entity. In this study, a platform with a 15x15 inch dimension was made manually. The platform was painted in black color for easy manipulation of the image. The center spot where the mango would be put into was calculated and modified through the simple application of geometry and arithmetic. The center spot was surrounded by four fixed points (53 inches away from the center point). The four points would serve as the indicator for the boundary of the image that would be captured during the acquisition. The points were fixed in a certain position to achieve the consistency of the images of the mango. A portable web-camera was used in this process. It was fixed above the platform with a height of 1.8 feet. A wood was attached beside the platform to hold the camera in position. The height of the camera from the platform was positioned in a way where it could capture the four points and the center point on the platform. The distance of the camera and the sample were also fixed and measured to achieve the consistency of the output. Proper lighting was also controlled and observed to assure the reliability of the result. An engineering software was used to save and load the images captured. The software used worked well with the images in multi color or monochrome state. Images of the mango samples captured and collected were also analyzed in the software. The images (input) captured were all primarily represented in RGB images.

Pre-processing

Feature Extraction method includes the collection of extracted qualities. The input images from the image acquisition are usually not ready for straight classification and identification because of certain factors, such as noise, climatic conditions, poor resolution and unwanted background. By the use of pre-processing, the input images are prepared to suit the actual classification, identification and sorting. The pre – processing was divided into three parts- one for the size, one for the color, and another for the spot detection of the sample.

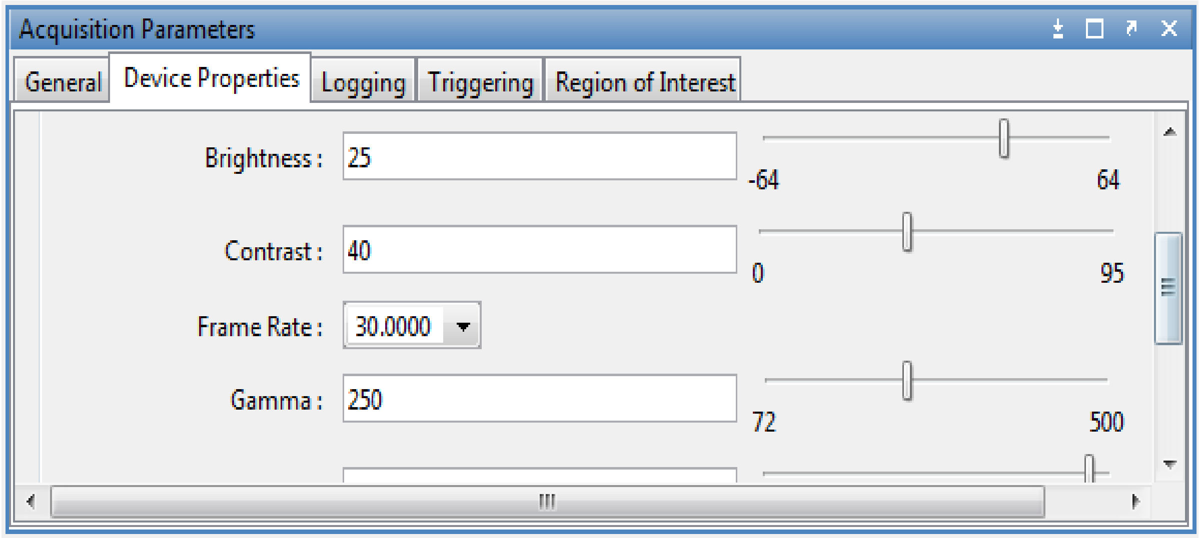
In this study, the researchers set first the values and parameters of the desired image that serves as the input or the main variable of this study. Setting the parameters enhances the quality of the image and increases the percentage of the accuracy of the results.

The steps involved in the pre-processing for the color are:

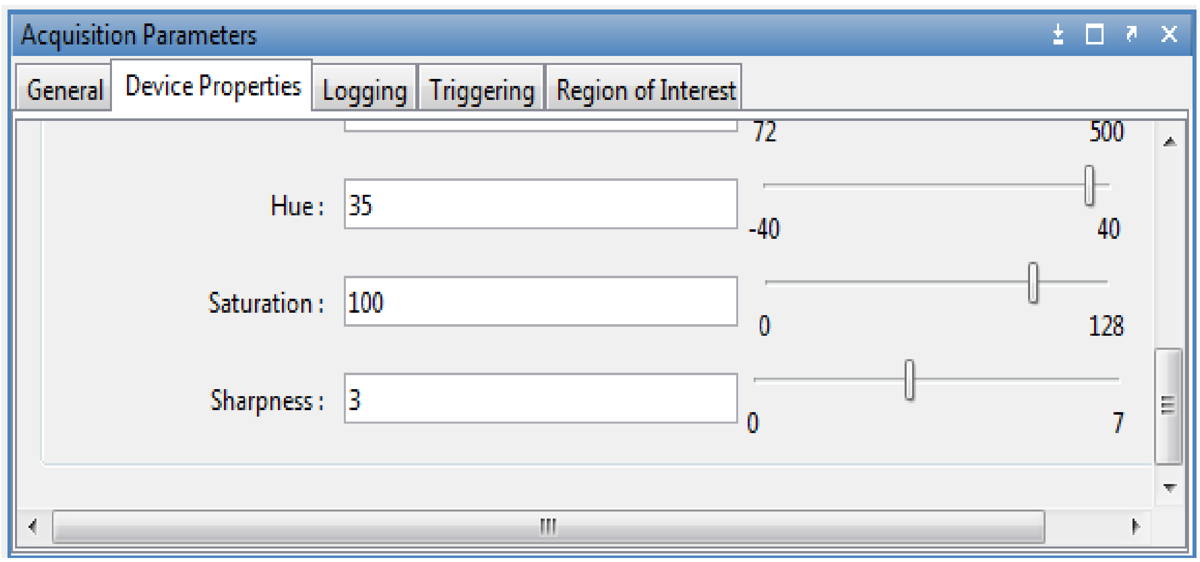
- Color Property Manipulation
- Setting of Reference Color

Color Property Manipulation

The input image is acquired using an Engineering Software. The format of the acquired image was fixed in a RGB color space. In this process, the input image was represented and limited to only three colors, specifically green, light-green and yellow. Each color had their individual and unique properties especially in the intensity level. The parameters were set before the image acquisition took place.



(A) For Brightness, Contrast, Frame rate, and Gamma



(B) For Hue, Saturation and Sharpness

Figure 4. Acquisition Parameters

Color saturation is defined as the intensity of the color. Hue is the property of a color that enables it to be perceived and determined by its dominant wavelength while luminance is the measure of brightness of a surface and equal to the luminous flux passing through a unit area of surface. Contrast is the degree and difference of lightness and darkness of the image. Sharpness defines the clarity of the image. Based on the experiment that the researchers have conducted, the manipulation of the saturation, luminance, hue, contrast and sharpness emphasizes the characteristics of the color. Controlling the properties also yields a better view or perception of the viewer on the sample and emphasizes the differences of each color more. The above figure shows the modification of the color characteristics on the image acquisition tool of the software.

Aside from having consistent results at the end, this modification was used to extract the quality and the differences of each color. The green color gives the darkest view while yellow produces the fairest perception. In this case, the color of the sample can now be identified in an easier manner. Furthermore, this step is done to reduce the confusion of the system when it comes to the identification of the color.

Setting a Reference Color

Setting a reference color is a very important task in this process. By setting this reference color, the system is able to identify and differentiate the three colors from one another. The reference color was set to color green. The reason why the green was set as the reference color is that it represents the color of the mango with a good quality for export. An experiment was first conducted to assure the values and consistency of the reference color.

The reference color (green) was first modified and made using a painting application. The maximum intensity of the color green was used. The maximum color contains values that would serve as the boundary from the other color.

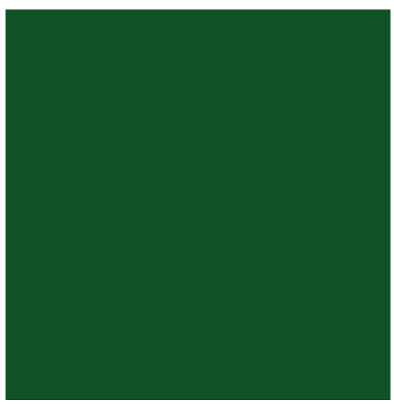


Figure 5. The Reference Color

The red, green and blue components were first extracted separately. They were then arranged in a matrix to get the determinant. The purpose of getting the determinant is to show the value in a simpler way and to avoid confusion and complexion on the results.

The *'double'* command returns the real-world value of a *fi* object in double-precision floating point.

The steps involved in the pre-processing for the size are:

- Input Image
- Conversion from RGB to Grayscale

- Thresholding/Filtering
- Centroid or Reference Point Identification

Input Image

The input image was acquired using engineering software. The image acquisition tool from the software was used to import the image captured from the web camera to the software. The captured image was first set in a RGB format. The parameters for brightness, contrast, gamma, hue, saturation and sharpness were first modified on the image acquisition tool for a better perception and analysis of the image. The camera was also modified into its maximum dimension for easier manipulation on the region of interest. The camera was set on a height from the platform where it can capture the center and the four surrounding points. These points are the vital indicators of the dimension of the image. The center point serves as the position where the mango is put into. The crop tool is used to crop the desired dimension of the image. The region or area where the points were located was cropped. The dimensions (in pixels) were further modified by setting the values in 450x450. This configuration was saved and used as the basis for the desired input image.

The mango samples used in the study were selected according to their class. Each mango has its characteristics that fell into one of the classes that the researchers had set, modified and surveyed.

The captured image from the mango sample is further analyzed on the software.

Figure 6. Input Image

The parameters set on the image acquisition tool:

Color Property	Value
Brightness	5
Contrast	40
Gamma	250
Saturation	3
Hue	35
Sharpness	25

Table 2. Parameters for every color property

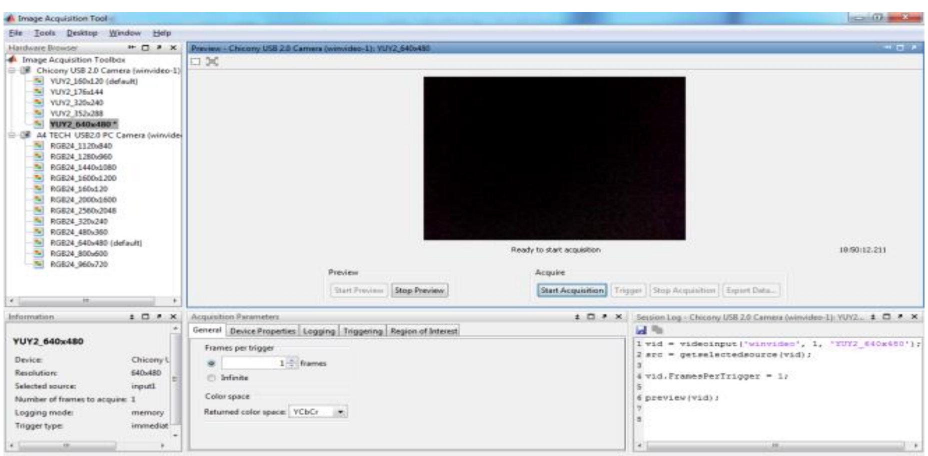


Figure 7. Image Acquisition Tool

Conversion from RGB to Grayscale

The images captured during the acquisition were converted from RGB to grayscale. The purpose of this process was to enhance the details of the image such as the edges, curves and the spots. Furthermore, this was used to prepare the image into the next process.

The conversion of the image to grayscale was done on the software. It is a command or syntax on the program that converts a certain input into a desired color space automatically.

Figure 8. The input image in a grayscale

Thresholding / Filtering

The main purposes of smoothing or filtering were to reduce the noise and improve the visual quality of the image. Smoothing was also used to avoid unwanted edges that can be measured during the measuring of the size of the sample. Accuracy should be achieved in extracting the size of the mango samples.

The researchers extracted the edges of the grayscale image by setting certain conditions or commands on the program. They further emphasized the edge of the image by dilation ('imdilate'). In this command, the edges were set to a thicker condition. The holes and the region (closed surface) of the image were then filled with white to emphasize the whole surface of the mango using 'imfill' (a command).

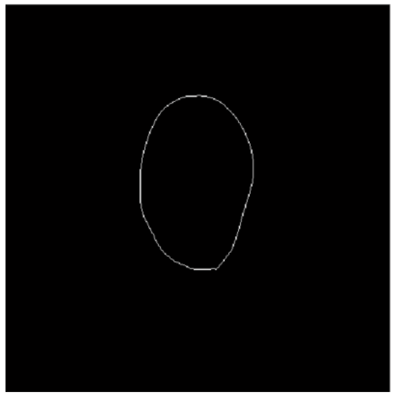


Figure 9. (A)Thresholding, (B) Dilation and (C) Filling

Centroid or Reference Point Identification

Centroid is defined as the point at the centre of any shape, also called centre of the area. The centroid is a vital variable in the identification of the size of the mango. In this study, the centroid was also called the reference point. The reference point is the point where the detection of the pixel originates or the starting point of detection. The reference point is fixed and identified by applying a simple arithmetic operation. The dimension of the image is set to 450 by 450 pixels. To get the center of each side, the pixel values of each side were divided by two. The whole image was represented by a matrix. Each pixel was also represented by a value of 'row' and 'column'. The center was originally set between 225X225 and 226X226 but there was no such thing as a pixel represented in 225.5X225.55 value. The researchers decided that the reference point should be fixed on the pixel with a 225x225 value using truncation and to avoid confusion on the program. It was also set on the said value to minimize the error in the identification of the size.

To find the center on the actual platform, the same process was also used. The unit used was in inches. The mango samples should be placed at the center. The top, bottom, left and the right parts of the mango was also taken into consideration. Visible lines on the platform are drawn to serve as an indicator for the position of the four vital parts of the mango. These four vital parts played a big role in the identification of the length and the width of the mango. They should be positioned properly on the platform to achieve desirable and precise results.

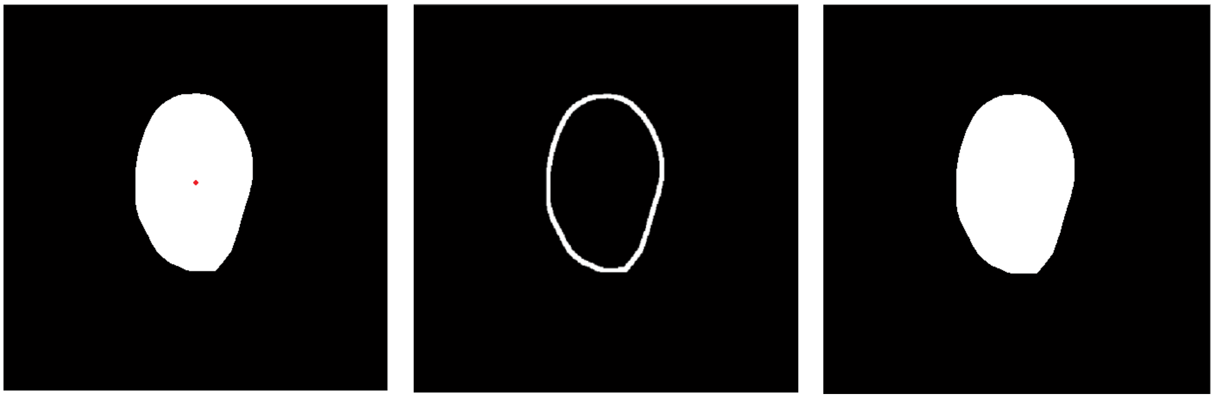


Figure 10. The input with its centroid

The steps involved in the pre-processing for the spot detection are:

- Conversion from RGB to Grayscale
- Thresholding/Filtering

Conversion of Image to Grayscale

The input image was primarily converted into a grayscale image. This process was the first step of extracting the needed features of the mango, specifically the edge and spots. By implementing the conversion of a RGB image to a grayscale image, important features like the edge, contour and curves were emphasized. This process simplified the conversion of the original image into binary form.

Figure 11. Conversion from RGB to Grayscale

Thresholding/ Filtering

Thresholding is one of the most important processes in this method. The same process of thresholding from size calculation was used in this method. The grayscale image was converted into a binary image where the edge of the mango and the spots were left. These edges from the mango and the spots were the variables needed in this process.

Figure 12. The threshold image

Feature Extraction

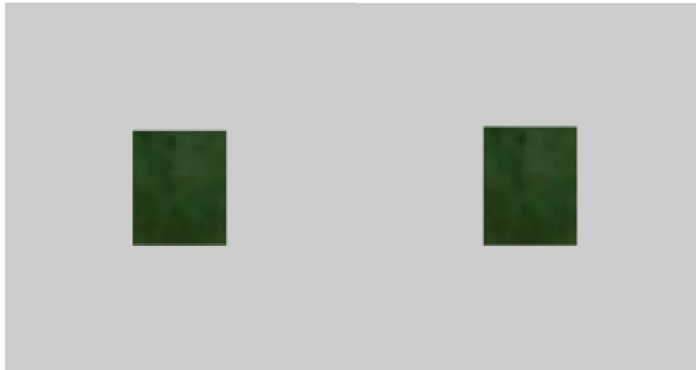
Color Identification

Every color is represented by specific RGB values. The software shows these RGB values in a more defined way. Using this software, the RGB numerical values are extracted from each color. The extracted values are compared or correlated from the reference color set before this process. The difference between the color of the input image and the reference color is shown by getting their determinant.

Both images (the input image and the reference color) were first cropped in a certain position, length and width). This position was located at the center of the image where the reference point for the size calculation was also located. The cropped portion was set to a bigger
area for the reliability of the result. The map (position) of the cropped area was copied to set on the '*imcrop'* command on both images (input and reference) to achieve consistency.

Figure 13. The input image with the position of the reference color

The cropped image was resized to get the proper matrix values of each image including the reference color. The process was also done to achieve their determinants (the determinant can only be achieved on square matrices).



(A) (B)

Figure 14. (A) Cropped Image (B) Resized Image

Correlation Method

Correlation Coefficient or *'corrcoef'* converts vectors into column vectors. It is also used to gather and compare elements of two variables. The input image was compared to the reference color. The result was first presented in matrix format. To evaluate the result in a simpler manner, the researchers had incorporated the finding of the determinant.

Size Identification

The size identification was the first major process in this study. The identification of the size was a complex process where the input image should be positioned precisely on the platform to achieve accurate results. Using the software, the input image was first processed into a more desirable format for the compatibility with the process of size calculation. Two major parts of the mango were used to identify the size of the mango - the major and the minor axis.

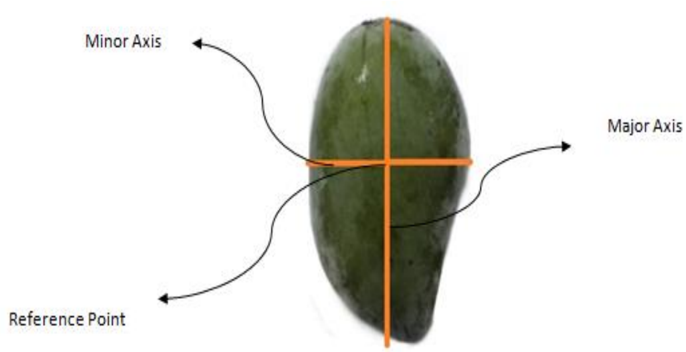


Figure 15. The input with its reference point, major, and minor axis

Pixel-Based Size Calculation

The major axis represents the length of the mango, while the minor axis represents the width. The reference point or the centroid is the center of the mango. Using the *'while expression'*, *'program statements'* and *'end'* on the program, the length and the width are identified. The *'while expression'*, *'program statements'* and *'end'* repeatedly executes the software program statements in a repeating way (loop). It continues until the expression
no longer holds the true statement or it encounters a *'break'* or *'return'* instruction, thus forcing an immediate stop of the loop code. When the software encounters a *'continue'* statement in the loop code, it stops or interrupts the execution of the loop code at the location of the '*continue'* statement. It begins another repetition of the loop at the *'while expression'* statement.

The *'expression'* is an expression on the software that evaluates the logical 1 (true) or logical 0 (false) expression. It can be a scalar or an array.It contains all the real elements. The *'expression'* usually consists of variables or smaller expressions joined by relational operators or logical functions. Simple expressions are combined by logical operators into compound expressions from left to right.

During the execution of the program, the pixels are counted from the reference point until it reaches the boundary of the program or where the statement becomes 'false'. That point where it stopped now becomes the maximum point of the mango.

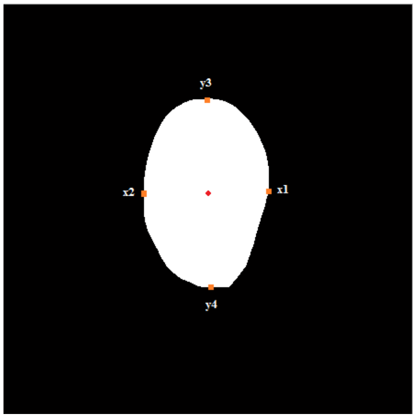


Figure 16. Binary Image showing its maximum points and centroid

The figure above shows the maximum points of the mango. The points indicate the region where the mango is cut-off.

Spot's Area/ Pixel-Area Calculation

The command *'bwarea'* calculates the area of objects in a binary image. It estimates the area of the objects in a binary format by summing the areas of each pixel in the image. The area of an individual pixel is determined by looking at its 2x2 neighborhood. The area is a scalar quantity whose value corresponds roughly to the total numbers of *'on'* pixels in the image, but not exactly the same because different patterns of pixels are weighted differently.

The values set on the statement of the program were derived or acquired from the tabulated average area of the edge of the mango. The values may vary depending on the camera used because of resolution differences. The resolution of the camera could also affect the results for the color and size identification.

This process contains the combination of the three qualities (the size, color, and number of spots) extracted from the mango fruit sample during the pre-processing. Each property contains distinct qualities. The converted data is combined by the program codes of the software.

Quality Combination

With the help of principles of counting in the basic counting techniques, distinct and unique categories was formed for the sorting process. Each property of the mango fruit sample has three qualities. For the size, it has small, medium and large qualities. For the color, it has the green, light-green and yellow qualities. For the spot, it has the *'spotless'* and *'spotted'* qualities. One quality from each property of the sample is combined together. From this, standard categories are derived where the combined qualities fall. Using the same software, the extracted and combined qualities are graded based on the standard categories made. A *'reject'* category was established for the samples not containing the qualities required in the market.

Through the use of surveying methods, the researchers were able to gather the needed information about the qualities of every category. The survey was conducted to fifteen mango producers and vendors in Pangasinan. Each person was provided a fill-up form to be filled with remarks and information about mango classes.

Logic System

The Logic System uses logic as a mathematical base. A logic program consists of sets of facts and if-then rules, which specify how one set of facts may be deduced from others. It also represents a strict set of rules for representing the relationships and interactions among numbers, words, symbols and other data stored or entered in the memory of the computer. (Microsoft Student, 2008)

In this study, the researchers presented a set of logical statements for every class. Each logical statement contains a unique set of qualities. The statement that gives true values to all the conditions or qualities set falls into one of the four categories (A, B, C, or D). The statement that does not satisfy either one of the conditions or qualities falls into the last category (E or Reject).

Output

The final output was presented in two ways - by a Graphical User interface and audio form. The researchers had presented the output in a way that the observer gets the needed information completely.

A Graphical-User Interface was structured where it enabled the user to choose commands, and start programs by pointing to pictorial representations and lists of menu items on the screen. It offered the users a direct interaction with the program and the computer. It provided the programmers standard controlling mechanisms for frequently repeated basic tasks. The choices were activated by a keyboard and a mouse.

It was modified directly on the software. A function was established for every method used in the program. This function was connected to every element in the GUI. The output for every method was also connected on every blank space intended for a certain result. It was done interactively for the benefit of the observers.

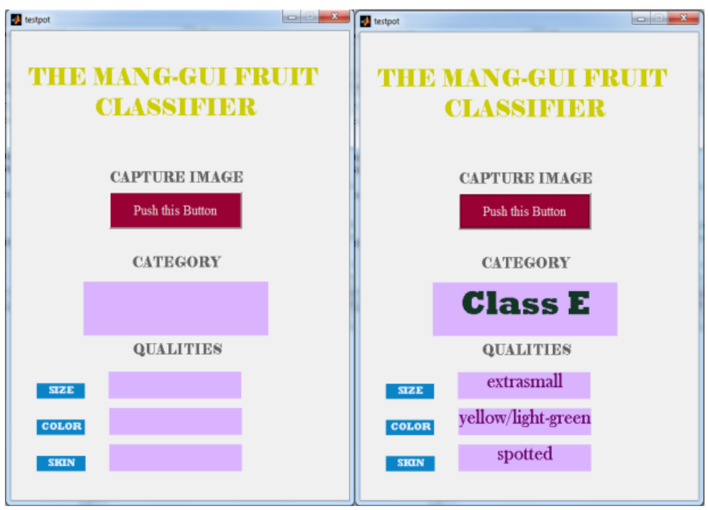


Figure 17. The Graphical – User Interface

The voice prompt output was done by recording the categories and its corresponding qualities. The recordings were processed and converted into a wav file in order for the software
to read it. The recordings were then imported to the software. The wav files were modified and synchronized with their corresponding category and quality.

Device Testing

The researchers conducted several tests of the system. Figure 17 shows the image of the constructed GUI. The mango sample was put on its specified location on the platform. A camera above captured the desired dimension and appearance of the image. The captured image was transferred to the software for processing and the application of the methods. The GUI served as the tool for executing the program easily. The *'press the button'* executed the capturing of the image and interpreting its category and qualities.

RESULTS AND DISCUSSIONS

Using the Automatic Classifier					**Manual Checking**				
Sample No.	**Size**	**Color**	**Skin**	**Category**	**Sample No.**	**Size**	**Color**	**Skin**	**Category**
1	LARGE	GREEN	SPOT LESS	A	**1**	LARGE	GREEN	SPOT LESS	A
2	LARGE	GREEN	SPOT LESS	A	**2**	LARGE	GREEN	SPOT LESS	A
3	LARGE	YELLOW	SPOT LESS	E	**3**	LARGE	YELLOW	SPOT LESS	E
4	MEDIUM	GREEN	SPOT LESS	B	**4**	MEDIUM	GREEN	SPOT LESS	B
5	MEDIUM	YELLOW	SPOT LESS	E	**5**	MEDIUM	YELLOW	SPOT LESS	E
6	LARGE	GREEN	SPOT LESS	A	**6**	LARGE	GREEN	SPOT LESS	A
7	LARGE	GREEN	SPOT LESS	A	**7**	LARGE	GREEN	SPOT LESS	A
8	MEDIUM	GREEN	SPOT LESS	B	**8**	MEDIUM	GREEN	SPOT LESS	B
9	EXTRA SMALL	GREEN	SPOT LESS	D	**9**	EXTRA SMALL	GREEN	SPOT LESS	D

10	SMALL	GREEN	SPOT LESS	C	**10**	SMALL	GREEN	SPOT LESS	C
11	LARGE	GREEN	SPOT LESS	A	**11**	LARGE	GREEN	SPOT LESS	A
12	MEDIUM	GREEN	SPOT LESS	B	**12**	MEDIUM	GREEN	SPOT LESS	B
13	MEDIUM	GREEN	SPOT LESS	B	**13**	MEDIUM	GREEN	SPOT LESS	B
14	EXTRA SMALL	GREEN	SPOT LESS	D	**14**	EXTRA SMALL	GREEN	SPOT LESS	D
15	EXTRA SMALL	LIGHT-GREEN	SPOT LESS	E	**15**	EXTRA SMALL	LIGHT-GREEN	SPOT LESS	E
16	LARGE	GREEN	SPOT LESS	A	**16**	LARGE	GREEN	SPOT LESS	A
17	LARGE	GREEN	SPOT LESS	A	**17**	LARGE	GREEN	SPOT LESS	A
18	LARGE	GREEN	SPOT LESS	A	**18**	LARGE	GREEN	SPOT LESS	A
19	LARGE	GREEN	SPOT LESS	A	**19**	LARGE	GREEN	SPOT LESS	A
20	MEDIUM	GREEN	SPOT LESS	B	**20**	MEDIUM	GREEN	SPOT LESS	B
21	MEDIUM	GREEN	SPOT LESS	B	**21**	MEDIUM	GREEN	SPOT TED	E
22	MEDIUM	GREEN	SPOT LESS	B	**22**	MEDIUM	GREEN	SPOT LESS	B

23	MEDIUM	GREEN	SPOT LESS	B	**23**	MEDIUM	GREEN	SPOT LESS	B
24	EXTRA SMALL	GREEN	SPOT LESS	D	**24**	EXTRA SMALL	GREEN	SPOT LESS	D
25	EXTRA SMALL	GREEN	SPOT LESS	D	**25**	EXTRA SMALL	GREEN	SPOT LESS	D
26	EXTRA SMALL	GREEN	SPOT LESS	D	**26**	EXTRA SMALL	GREEN	SPOT LESS	D
27	EXTRA SMALL	GREEN	SPOT LESS	E	**27**	EXTRA SMALL	GREEN	SPOT LESS	E
28	EXTRA SMALL	GREEN	SPOT LESS	E	**28**	EXTRA SMALL	GREEN	SPOT LESS	E
29	EXTRA SMALL	GREEN	SPOT LESS	D	**29**	EXTRA SMALL	GREEN	SPOT LESS	D
30	LARGE	GREEN	SPOT LESS	A	**30**	LARGE	GREEN	SPOT LESS	A
31	MEDIUM	GREEN	SPOT LESS	B	**31**	MEDIUM	GREEN	SPOT LESS	B
32	EXTRA SMALL	GREEN	SPOT LESS	D	**32**	EXTRA SMALL	GREEN	SPOT LESS	D
33	SMALL	LIGHT-GREEN	SPOT LESS	E	**33**	SMALL	LIGHT-GREEN	SPOT LESS	E
34	LARGE	LIGHT-GREEN	SPOT LESS	E	**34**	LARGE	LIGHT-GREEN	SPOT LESS	E
35	LARGE	YELLOW	SPOT LESS	E	**35**	LARGE	YELLOW	SPOT LESS	E
36	LARGE	GREEN	SPOT LESS	A	**36**	LARGE	GREEN	SPOT LESS	A
37	EXTRA SMALL	GREEN	SPOT LESS	D	**37**	EXTRA SMALL	GREEN	SPOT LESS	D
38	EXTRA SMALL	GREEN	SPOT LESS	D	**38**	EXTRA SMALL	GREEN	SPOT LESS	D

39	MEDIUM	GREEN	SPOT LESS	B	**39**	MEDIUM	GREEN	SPOT LESS	B
40	MEDIUM	GREEN	SPOT LESS	B	**40**	MEDIUM	GREEN	SPOT LESS	B
41	EXTRA SMALL	GREEN	SPOT LESS	E	**41**	EXTRA SMALL	GREEN	SPOT LESS	E
42	MEDIUM	GREEN	SPOT LESS	B	**42**	MEDIUM	GREEN	SPOT LESS	B
43	SMALL	YELLOW	SPOT TED	E	**43**	SMALL	YELLOW	SPOT TED	E
44	MEDIUM	YELLOW	SPOT TED	E	**44**	EXTRA SMALL	YELLOW	SPOT LESS	E
45	EXTRA SMALL	YELLOW	SPOT LESS	E	**45**	EXTRA SMALL	YELLOW	SPOT LESS	E
46	LARGE	YELLOW	SPOT LESS	E	**46**	LARGE	YELLOW	SPOT LESS	E
47	SMALL	YELLOW	SPOT TED	E	**47**	SMALL	YELLOW	SPOT TED	E
48	SMALL	YELLOW	SPOT TED	E	**48**	SMALL	YELLOW	SPOT TED	E
49	LARGE	YELLOW	SPOT TED	E	**49**	LARGE	YELLOW	SPOT TED	E
50	MEDIUM	YELLOW	SPOT TED	E	**50**	SMALL	YELLOW	SPOT TED	E
51	SMALL	YELLOW	SPOT TED	E	**51**	SMALL	YELLOW	SPOT TED	E
52	MEDIUM	LIGHT-GREEN	SPOT TED	E	**52**	MEDIUM	LIGHT-GREEN	SPOT TED	E
53	MEDIUM	GREEN	SPOT LESS	B	**53**	MEDIUM	GREEN	SPOT LESS	B
54	SMALL	GREEN	SPOT LESS	C	**54**	SMALL	GREEN	SPOT TED	C

55	SMALL	GREEN	SPOT LESS	C	**55**	SMALL	GREEN	SPOT LESS	C
56	EXTRA SMALL	YELLOW	SPOT LESS	E	**56**	EXTRA SMALL	YELLOW	SPOT LESS	E
57	LARGE	YELLOW	SPOT LESS	E	**57**	LARGE	YELLOW	SPOT LESS	E
58	SMALL	YELLOW	SPOT LESS	E	**58**	SMALL	YELLOW	SPOT LESS	E
59	SMALL	YELLOW	SPOT LESS	E	**59**	SMALL	YELLOW	SPOT LESS	E
60	SMALL	LIGHT-GREEN	SPOT TED	E	**60**	SMALL	LIGHT-GREEN	SPOT TED	E

Table 3. Testing and comparison results for the mango sample

No. of Unmatched Classification = 4 (6.6667%)
No. of Matched Classification = 56 (93.33%)

The table above shows the comparison between the traditional sorting and the automatic classification of the mango samples. The number of unmatched classifications is seven or 6.6667%. The number of unmatched classifications is 56 or 93.333%. The low percentage of the number of unmatched classifications implies higher accuracy in terms of matching computer-based classification to manual sorting.

The automatic classification was done in the Graphical User Interface of the software. The samples were first manually classified by mango producers and experts. The results for every sample were listed and tabulated. After the manual and actual classification, the results were compared. The results show that the system has a good accuracy rate based on the number of matched classifications. They also show that the classifications for size and color were the most accurate among the three classifications.

For Color

Color	Total Samples	Correctly Classified Samples / Manually Sorted	Accuracy
Green	60	60	100%
Light-Green	60	60	100%
Green	60	60	100%
Average Accuracy			100%

Table 4. Accuracy Rate for Color

For Size

Size	Total Samples	Correctly Classified Samples / Manually Sorted	Accuracy
Large	60	60	100%
Medium	60	59	98.33%
Small	60	60	100%
Extra-Small	60	60	100%
Average Accuracy			99.58%

Table 5. Accuracy Rate for Size

For Spots

Skin Appearance	Total Samples	Correctly Classified Samples / Manually Sorted	Accuracy
Spotless	60	59	98.33%
Spotted	60	59	98.33%
Average Accuracy			98.33%

Table 6. Accuracy Rate for Spot

Overall Accuracy

Total Samples	Correctly Classified Samples / Manually Sorted	Accuracy
60	56	93.33%
Average Accuracy		93.33%

Table 7. Overall Accuracy

Table 4 indicates a 100% accuracy when it comes to color detection. Table 5 indicates a 99.58% of accuracy in terms of determining the size. Table 6 designates a 98.33% accuracy rate for spot detection. The color identification got the highest percentage of accuracy while the spot detection got the lowest percentage of accuracy. By statistical analysis, the tables show that the system achieved a 93.33 % accuracy.

CONCLUSION

The proposed study was successfully structured and tested. The system was designed to determine the category of the mango fruit samples according to their qualities, specifically the size, color and the spots. A handmade platform with a camera and a computer was used in the study. Different methods and algorithms were implemented to extract the needed physical qualities of the input sample. These methods were the pixel-based size calculation for determining the size, correlation method for determining the color and the pixel-area calculation for getting the area of spots. The color, spots and the size were successfully extracted. The parameters in grading the mangoes were categorized into Class A, B, C, D, and E. These qualities were successfully combined, sorted, and identified according to the established category. The researchers had undergone a series of experimentations, tests, researches and surveys to construct the whole system. Experiments show that the proposed methods have good accuracy and reliability. The study yielded an overall accuracy of 93.33 %.

The device shall undergo some improvements like any other systems though the implementation of the study was proven and accepted. Future researchers may improve the design of the mango fruit classifier. The researchers should innovate the system in terms of its capability to sort the inputs where the shape of the mango should also be taken into consideration. They can also improve the image acquisition stage by investing on a mechanical conveyor instead of a platform, use additional cameras for further analysis of the input and control the lighting conditions to achieve better results. The ability to improve the processing time during the sorting process should also be improved. Furthermore, the output (GUI and voice prompt) can be replaced by a more interactive tool. The researchers further concluded that this system must be given a worthwhile recommendation and implementation.

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