

# Fruits Sorting and Grading using Fuzzy Logic

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**Abstract** – Now a days, the classification and grading is performed based on observations and through experience. The system utilizes image-processing techniques to classify and grade fruits. The developed system starts the process by capturing the fruit's image using a regular digital camera. Then, the image is transmitted to the processing level where feature extraction, classification and grading is done using MATLAB. The fruits are classified based on color and graded based on size. Both classification and grading are realized by Fuzzy Logic approach. The results obtained are very promising.

**Keywords** – Features Extraction, Sorting, Grading and Fuzzy Logic.

## 1. INTRODUCTION

Agriculture is the largest economic sector and it plays the major role in economic development of India. The manual classification and grading techniques which are being used to distinguish between different types of fruits are completely relying on human resource. Since these techniques are guided by human intervention, they are subject to some kind of errors. Since humans are subjected to tiredness and due to the shortage of labors, automated system needs to be incorporated to minimize the work and the automated system also helps to reduce the time consumed by manual techniques.

Many new agricultural automation technologies are being developed by university researchers that pose questions about the efficiency and effectiveness with which we carry out current agricultural practices.

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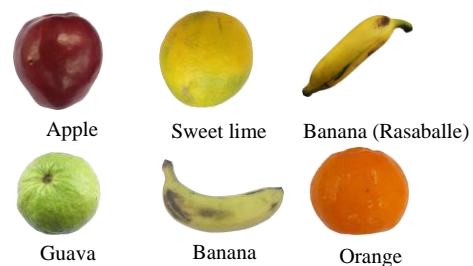
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This has given rise to many new opportunities to service the agronomic requirements albeit in radically different ways to those currently used. Fruits are delicate materials, so they should be tested via non-destructive techniques. Classification is vital for the evaluation of agricultural produce. Fruit size is the most important physical property while color resembles visual property. Hence, classification of fruits is necessary in evaluating agricultural produce, meeting quality standards and increasing market value. It is also helpful in planning, packaging, transportation and marketing operations. If the classification and grading is done through manual techniques, the process will be too slow and sometimes it will be error prone. The labors classify based on color, size, etc. if these quality measures are mapped into automated system by using suitable programming language then the work will be faster and error free.

The proposed automated classification and grading system is designed to combine three processes such as feature extraction, sorting and grading. Software development is highly important in this color classification system. The entire system is designed over Matlab software to inspect the color and size of the fruit. Color of the fruit is very important in classification but since due to the similarity of colors between some fruits, the size also helps in solving this kind of problems. The color and size based classification involves extracting the useful information from the fruit surface and classify it to the respective type.

This automated system is designed to overcome the problems of manual techniques. The image could be captured using a regular digital camera or high resolution mobile phone camera. This image is given as an input to the system for obtaining the fruit's features. The system consists of several steps like feature extraction, sorting and grading.



**Fig. 1: Set of fruits**

The main advantage of this application is to classify and grade the fruits. In this application

as shown in fig.1, two kind of bananas, apple, orange, guava and sweet lime has been used to classify and grade. Based on the fruit's color and length, the fruit is classified to its class. The grade is determined based on fruit's area and width by using Fuzzy Logic. Fuzzy logic is a logical system, which is an extension of multivalued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human-like way of thinking in the programming of computers. Fuzzy Logic has emerged as a profitable tool for the controlling and steering of systems and complex industrial processes.

## 2. PREVIOUS WORK

(Njoroge et al.,) have developed an automated grading system using image processing where the focus is on the fruit's internal and external defects. The system consists of six CCD cameras [1]. Two cameras are mounted on the top, two on the right and another two cameras mounted on the left of the fruit. X-ray imaging is used for inspecting the biological defects. Image processing is used to analyze the fruit's features; size, color, shape and the grade is determined based on the features. The developed system is built from a combination of advanced designs, expert fabrications and automatic mechanical control.

(Ismail Kavdir and Daniel. E Guyer et al., 2003) have developed a system which grade apples by using color and size [2]. Fuzzy logic system designed for this purpose. Grading results obtained from fuzzy logic showed 89% general agreement with the results from the human expert, providing good flexibility in reflecting the experts' expectations and grading standards into the results. This application of apple grading can be fully automated by measuring the required features by means of high-tech sensors or machine vision and making the grading decision using fuzzy logic.

(Wen-Hung Chang and Suming Chen et al.,) have developed a vision based system for classifying the fruits. It is based on measures of fuzziness and degree of matching. Fuzzy approaches were used to determine optimal thresholding values of fruit's images and fuzzy degree of matching was applied to classify the color and size of fruits [3]. Results showed that fuzzy method was superior to the traditional statistical methods and a better accuracy of 93.3% for combined sorting was reported. The errors due to miscategorization could thus be reduced if the fuzzy methods were used. The developed fuzzy algorithms were integrated with machine vision guiding robotic sorting system for fruits.

(Guo Feng and Cao Qixin et al., 2004) have made study on Color image processing based intelligent fruit sorting system in which fruit's color ratio, which was calculated with HSI color space, was selected as classification feature [4]. Fruit sorting was realized by classic Bayes classifier, whose parameters were obtained by a study module.

(Nur Badariah Ahmad Mustafa, Syed Khaleel Ahmed, Zaiyatimah Ali, Wong Bing Yit, Aidil Azwin Zainul Abidin, Zainul Abidin Md Sharrif et al.,) have proposed automated grading system to classify four types of fruits and a vegetable namely apples, bananas, oranges, mangoes and carrots [5]. The features such as area, major axis, minor axis and perimeter have been used to classify the samples. In this paper, technique such as support vector machine is used to classify the samples and fuzzy logic to grade the classified samples.

(A.N.Lorestani, M.Omid, S. Bagheri Shooraki, A.M. Borghei & A. Tabatabaefar et al., 2006) have made their work on Design and Evaluation of a Fuzzy Logic Based Decision Support System for Grading of Golden Delicious Apples in which size and color features are extracted and fuzzy logic technique has been used to grade the apples [6].

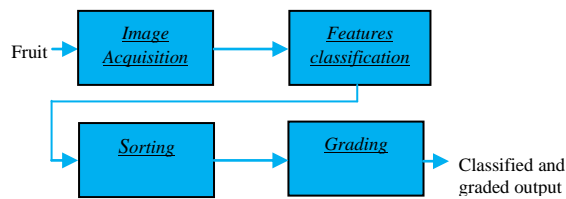
(Ling Mei Chan, Rodney Tan, Gilbert Thio et al.,) have made research on Design of Visual-based Color Classification System in which the system consists of a color webcam interfaced to the computer [7]. The entire system operates on a Matlab driven program that analyzes the color of the objects being inspected. The main idea of this study is to understand the use of color in machine vision and to enhance the color processing in PC-based vision systems. The theory of operation for this system includes the process of dithering, calculation of the mean values and histograms, and the final result. Experimental results obtained from different fruits are analyzed and tabulated. One of the potential applications is to segregate the ripe and unripe fruits. This system is fundamentally capable of identifying four types of tropical fruits.

## 3. SYSTEM DESIGN

In designing the system, modules, constraints and components are to be considered. The purpose of design phase is planned solution of problem specified by the requirements document. This phase is first step in moving from the problem domain to the solution domain. The output of this phase is design documents.

The architectural design is concerned with establishing a basic structure of a system. It involves identifying the major components of the system and communications between these components. 1-tier architecture is best suited for

our proposed system as it is based on simulation. As our project is executed in one system where everything resides in a single program, one tier is best applicable. The overall process is shown here.

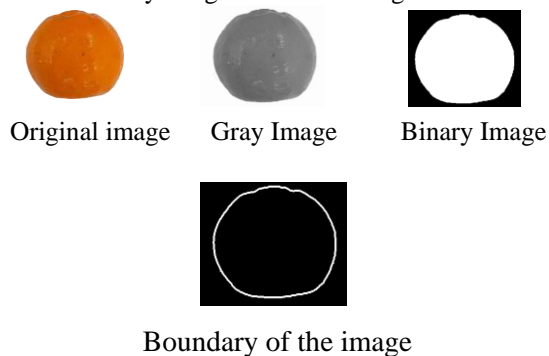


**Fig. 3.1: flow chart of sorting and grading**

### process

#### 3.1 Feature Extraction

Feature extraction is the process of measuring or calculating the features from the image samples such that which are sufficient to distinguish between one type of image from another type. Certain fruits can be easily identified by color and size. The feature extraction process is done using the MATLAB image processing toolbox. The extraction process begins with the conversion of the original image to gray image and then to binary image as shown in Fig. 3.2



**Fig 3.2: Boundary extraction**

The boundary of each object is detected as shown in fig.3.2. The major and minor axis length represent the actual length and width of a fruit. This measurement together with the area, determines the size of a fruit. The major axis length of the fruit is the length (in pixels) of the major axis of the ellipse while the minor axis length is the length of the minor axis of the ellipse. For finding the actual measurements of the sample a reference object of known dimensions is used. A 2 rupee coin has been used to translate the pixel value to exact area, length, and width. The measurements of area, length, width of a the coin are noted manually in prior. The dimensions of the coin in pixels are also obtained in advance using Matlab functions. The calculations which will convert pixel values area, majoraxis and minoraxis of an object to exact area, length and width are as follows.

coin majoraxis length = 2.7 cm  
 coin minoraxis length = 2.7 cm  
 coin area =  $3.142 \times 1.35 \times 1.35 = 5.72$  cm

coin majoraxis length in pixels = 161.0001  
 coin minoraxis length in pixels = 161.7041  
 coin area in pixels = 1350

coin pixels : fruit pixels  
 coin area,major,minor : fruit area,major,minor

fruit area = fruit pixels X coin area / coin area pixels

fruit area = fruit pixels X 5.72/1350

fruit area = fruit pixels X 0.00424

fruit majoraxis = fruit pixels X coin majoraxis / coin major pixels

fruit majoraxis = fruit pixels X 2.7 / 161.0001

fruit majoraxis = fruit pixels X 0.01667

fruit minoraxis = fruit pixels X coin minoraxis / coin minor pixels

fruit minoraxis = fruit pixels X 2.7 / 161.7041

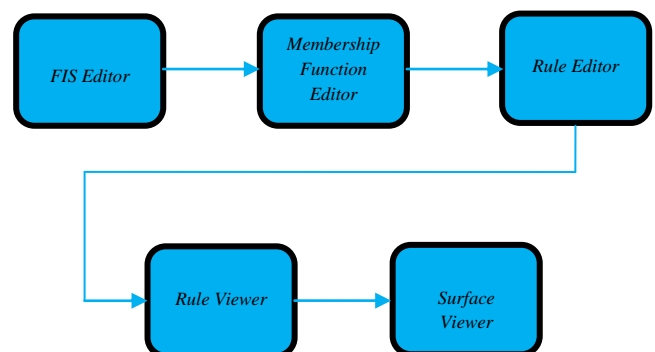
fruit minoraxis = fruit pixels X 0.01679

#### 3.2.Sorting and Grading

It is desirable to have a system that has the ability to recognize the size and color of an object. Such a system can be used for fruit sorting. A technique for recognizing the fruit shape is proposed here. Fuzzy logic have been used to sort the fruits to their respective classes[8], [9]. The fuzzy logic consists of

1. FIS Editor
2. Membership Function Editor
3. Rule Editor
4. Rule Viewer
5. Surface Viewer

The fuzzy inference system is shown in fig. 3.3.



**Fig. 3.3: Fuzzy inference system**

#### 1. FIS editor

The FIS Editor handles the high-level issues for the system: How many input and output

variables? What are their names? Fuzzy Logic Toolbox software does not limit the number of inputs. However, the number of inputs may be limited by the available memory of your machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other GUI tools.

## 2. Membership Function Editor

The Membership Function Editor is used to define the shapes of all the membership functions associated with each variable.

## 3. Rule Editor

The Rule Editor is for editing the list of rules that defines the behavior of the system.

## 4. Rule Viewer

To view the fuzzy inference diagram.

## 5. Surface Viewer

To view the dependency of one of the outputs on any one or two of the inputs—that is, it generates and plots an output surface map for the system.

The process begins with defining the number of system inputs and outputs followed by the definition of input and output membership functions. Finally, the rules are constructed using IF-THEN statements. In the rule editor, the expert knowledge (human experience) is captured for influencing the decision making process. Basically, the system behaves according to the rules set by the expert. Hence this is a critical step in the grading process. The rule and surfaceviewer are the graphics that are used to view the built system. The rule viewer is a MATLAB based display of the fuzzy inference system which is built from membership functions and rules. It is used as a system diagnostic where it can show the rules that are active or how individual membership function shapes influence the results. The surface viewer is used to display the dependency of the outputs on the input. It generates and plots the output surface map for the system.

The color features red, green, yellow and geometric feature minoraxis have been used to classify the samples. These extracted features are given as input to the fuzzy system and the defuzzification result is an output of classification.

The geometric features such as area, majoraxis length are used to grade the fruits to low or high. Again the values are defuzzified and sample is graded.

## 4.IMPLEMENTATION

The implementation phase begins with fruit sample being captured using regular digital camera with white background with the help of a stand. The image is loaded into matlab for processing. The features such as color content and minoraxis are extracted for sorting and parametres such as area and majoraxis length are extracted for grading the sample image. There are different modules which will perform different operations on the image being loaded. The modules are :

- Image capture
- Boundary extraction
- Geometric features extraction
- Color features extraction
- Classify the sample
- Grade the sample

### 4.1 Image Capture

An image of the fruit is captured by using a digital camera or any mobile phone camera. This image is loaded into the matlab by using the function 'imread'. This function reads the image from the specified path. The image is stored in the matrix form of rows and columns . If is a grayscale image, then it is stored as an M-by-N array. If the file contains a truecolor image or RGB image, then it is stored as an M-by-N-by-3 array. The syntax for selecting an image is

*imread(filename,fmt)*

which reads a grayscale or color image from the file specified by the string filename. If the file is not in the current directory, or in a directory on the MATLAB path, specify the full pathname. The text string *fmt* specifies the format of the file by its standard file extension, for example: \*.jpeg, \*.jpg, \*.bmp, etc.

### 4.2 Boundary extraction

As it is an colored input, it need to be converted to grayscale by function 'rgb2gray(image)' and the syntax is

*I=rgb2gray(RGB)*

which converts the truecolor image RGB to the grayscale intensity image I. rgb2gray converts RGB images to grayscale by eliminating the hue and saturation information while retaining the luminance and then the image is converted to binary before it is used for further processing in which image consists of only two colors namely black and white. The corresponding syntax is

*BW = im2bw(I, level)*

that will converts the grayscale image I to a binary image. The output image BW replaces all pixels in the input image with luminance greater than level with the value 1 (white) and replaces all other pixels with the value 0 (black). The matrix consists of only 0's and 1's. Thus such an image is



used to extract the boundary. The pixels in the image whose pixels which are less than 225 are set to 0. Since the image is taken with white background, the background will be having pixel value of 255 indicating white color. Thus the fruit image is made completely black. Again the function `strel` is used which creates a structuring element of type disk shape.

The negation of first binary image is taken in which results into fruit will be in white color and background will be in black color. The dark patches or holes present in the image are filled using the function `'imfill()'`. Its syntax is

$BW2 = \text{imfill}(BW, 'holes')$

that fills holes in the binary image `BW`. A hole is a set of background pixels that cannot be reached by filling in the background from the edge of the image. Finally `'imerode()'` function is used to erode the image by structuring element. The boundary of an image is obtained by subtracting the main image and the eroded image. The syntax for `imerode` is

$IM2 = \text{imerode}(IM, SE)$

which erodes the grayscale, binary, or packed binary image `IM`, returning the eroded image `IM2`. The argument `SE` is a structuring element object or array of structuring element objects returned by the `strel` function. If `IM` is logical and the structuring element is flat, `imerode` performs binary erosion; otherwise it performs grayscale erosion.

#### 4.3 Geometric features extraction

This module begins with the extracted boundary of the object. The function used to trace the features is `'regionprops'`. The main features extracted are Area, Majoraxis and Minoraxis. The syntax for `regionprops` is

$STATS = \text{regionprops}(BW, properties)$

that measures a set of properties for each connected component (object) in the binary image, `BW`. The image `BW` is a logical array; it can have any dimension.

#### 4.4 Color features extraction

The colors used for classification are red, green and yellow as there is a difference between the fruit's skin based on these colors. Hence these colors are helpful for sorting out the fruits. The red and green component is calculated by counting pixel values corresponding the red and green colors and yellow component is calculated by first converting the RGB image to CMY by using the function `'imcomplement(RGB)'` and the syntax is

$IM2 = \text{imcomplement}(IM)$

#### 4.5 Sorting the samples

Classifying the samples is the method of separating one kind of sample from another. In this

case, one kind of fruit is separated from the other set of fruits. Fuzzy Logic method is used here. Mamdani-type inference, as defined for the toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification.

The syntaxes used here for fuzzy system are

$fismat = \text{readfis}('filename')$

read a fuzzy inference system from a .fis file (named filename) and import the resulting file into the workspace.

$output = \text{evalfis}(input, fismat)$

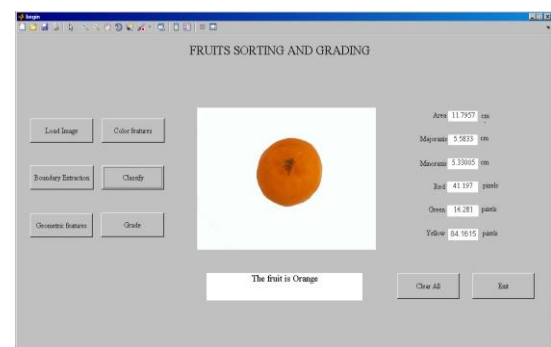
`evalfis` has the following arguments:

#### 4.6 Grading the samples

Grading the fruit is extracting the size of the fruit as the size is an important criterion related to the market value of the fruit. Hence grading the fruit is important for the farmers before they sell their produce. In this project, fruit is graded to low or high based on the geometric features of the fruit namely area and major axis.

### 5. RESULTS & ANALYSIS

The results and analysis step is the final step in which outcome of the project is being displayed. The GUI is created for the user with proper buttons to use them on the query image and features of the object are displayed directly on to the screen. The comments regarding the query image are displayed on the text box. The query image is displayed in the axis box.



The features of the query image are

- Area : 11.7957 cm
- Major axis : 5.5833 cm
- Minor axis : 5.33005 cm
- Red : 41.197 pixels
- Green : 16.281 pixels
- Yellow : 84.1615 pixels

Initially during classification, the colors red, green and yellow and geometric feature minor axis is chosen. As the inputs for first classification are red and yellow there are two sets namely set1 which is having the yellow color range between 46

to 95 pixels and red color range between 0 to 19.95 pixels and set2 which is having the range 96 to 108 pixels of yellow color and 20.1 to 64 pixels of red color. Hence defuzzification value of other than 0.75 is outputted. This confirms that the fruit is orange or sweet lime. In the next step, green color component is used to distinguish between orange and sweet lime. The inputs for the fuzzy system is green and the defuzzified output is in the range 0 to 0.5 which confirms the fruit is orange. As the area and major axis of query image are 11.7957 cm and 5.5833 cm respectively, the defuzzified output of value other than in the range 0.33 to 0.5 is obtained which confirms the fruit grade is high.

## 6. CONCLUSION & FUTURE WORK

This work presents a new technique for sorting and grading of fruits. This technique begins with capturing the fruit's image using regular digital camera. The features are efficiently extracted from the query image. The color of the fruit determines its class and fruit's grade is determined by its size. The fuzzy logic technique is used for both classification and grading of fruits, as it also involves decision making by humans. The proposed technique accurately classifies and grades the fruits. The results are good for the five chosen fruits of same color and sizes. This kind of system can be employed in Agriculture Produce Marketing Corporation, etc.

### 6.1 Future work

The proposed method has classified fruits with same color and fruits with same sizes. But since there will some kind of fruits with same color as well as same size. For ex. fruits such as tomato and apple will be having same color and size, so there will be misclassification related to those kinds of fruits. Hence one more feature, namely texture need to be considered while classifying such kinds of fruits. The images captured are taken by using white background, hence to make a system more robust, it should be modified to provide correct output for any kind of backgrounds.

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