# Smart Farm: Automated Classifying and Grading System of Tomatoes using Fuzzy Logic

Lenard C. Dorado[1*], Jules Ian C. Aguila[1], Rionel B. Caldo[1]

[1]*Computer Engineering Department, Lyceum of the Philippines University - Laguna*

[*]lenarddorado@gmail.com

**ABSTRACT**

*Manual operation is considered as a big factor in a low production and the Smart Farm System is one way that can address this problem by improving and increasing the quality and quantity of production by making farms more intelligent and more connected through the precision agriculture. With that, the proponents will develop a system through smart farm system that is capable of classifying and grading the tomatoes. This process will be done automatically using image processing and fuzzy logic. There will be a Fuzzy Inference Systems to be established using MATLAB software to classify and grade the tomato fruit. In classifying, system will determine if tomato is damaged or not. On the other hand, system will distinguish if a specific fruit or crop is under ripe, ripe or overripe in grading. It is believed that this study is of great help to farmers for high yield and productive plant harvests.*

***Keywords:*** *Smart Farm System, image processing, Fuzzy Logic, Fuzzy Inference System, MATLAB*

## 1. Introduction

This chapter explains the motivation for pursuing this work. It is stylized into four sections: background of the study, objectives and its significance and the scope and limitation of the study. The chapter would serve as a basis for what the study will attain.

### 1.1 Background of the Study

Philippines is considered as an agricultural country due to its tropical weather and non-damaging climate. Farming has been the main job of Filipinos especially crop farming where land is used for growing of fruit, vegetable and grain. Farmers have many kind of works and it is all through the human effort and a lot time was needed to accomplish all the chores. And not to mention how broad the farm is, the manual operation is considered as a big factor in a low production. The classifying and grading process for packaging purposes is specifically one of the manual operations being used. It is completely relying only on human resource and the inspection will be liable to some sort of errors [5]. Much more, that human body and mind get tired easily within a couple of hours. Also, the examining or checking of the solidness and nature of each crop are wasting a major part of the time and it additionally expends the ideal opportunity for other part of the work.

One way that can address this problem and increase the quality and quantity of production is through the system which made farms more intelligent and more connected through the precision agriculture, also known as Smart Farm System. It is capable of helping the farmers to make their work easier and faster. It is composed of different subsystems that divides the whole system into its operation category. The automated classifying and grading system is one of the subsystems under smart farming which considered as helpful in the production through its functionality. This process enables crops like

fruits and vegetables be sorted and graded according to its specified feature depending on the system. Fruits and vegetables are fragile materials, so that the techniques that should be used for grading must be a non-destructive procedures.

All of these were just have been considered by the proponents so that they have come up with idea of developing a classifying and grading system focusing on tomatoes. Since tomatoes is considered as a frail material, it is the best sample to see how the manual operation affects its production. The system will be developed using a machine vision system for image processing through the MATLAB software as well as the fuzzy logic for the evaluation of the processed image providing a Fuzzy Inference System (FIS).

**1.2. Objectives of the Study**

The general objective is to apply the smart farm system through the classifyingg and grading system of tomatoes using Fuzzy Logic. And their specific objectives are:

- To capture tomato images and detect the feature using image processing
- To provide a Fuzzy Inference System for the evaluation of input data from the processed image
- To classify the Apollo tomatoes by sorting its quality if it is good or bad
- To grade the Apollo tomatoes by determining the level of ripeness if it is under ripe, ripe, or overripe through the system
- To test the accuracy and functionality of the system

**1.3 Significance of the Study**

Tomatoes is considered as a fragile material and it is easily damaged when it was bruised. Tomatoes are prone to damage because of the processes it undergo before sending them to markets. Since tomatoes is considered that has a high demand in market, the factors of having many damaged can affect the production. So that the classifying and grading system was befitted to the problems because it is a method or a technique which is a non-destructive procedure.

Furthermore, through the smart farm system, classifying and grading technique will be developed not specifically to stop the manual operation in whole farming but rather to assist the farmers in the aspect of checking the quality of crops. The importance of the system is to lessen the high demand of work and the delayed of task due to so many work.

The system was also developed in a way that the process is continuous. After classifying if it is good or bad, good crop will directly proceed to grading where it will immediately determine its level of ripeness. Since bad quality crops is no longer included for selling, farmers will easily pick up the combined-classified bad quality crops and use it for some purposes. Therefore, the system will be significant in terms of time consuming work.

Moreover, the automated classifying and grading will help avoid the possible errors in production due to wrong checking and estimation. This system is very timely for our country's agriculture since we lack tools and equipments. The role of this system is not

only for the sake of the farmers but also a partial help to our agriculture.

### 1.4. Scope and Limitations

The development of the system has a purpose of assisting the farmers for the classifying and grading process since they only used their own technique or their experience.

In this developmental study, hardware and software will be used for the fabrication of the system. The help of the conveyor system will further improve the system by applying it as a mechanical control through Arduino. Machine vison system and software applications will also be used. Also, fuzzy logic will be used for the evaluation and classification of processed image will provide Fuzzy Inference System for the variable.

The Automated Classifying and Grading System will be using tomatoes as variable for experimentation. The fruit was chosen beacuase it was very timely considering its high demand in markets.

The study was only limited to the demonstration of the accuracy and functionality of the system. These two will be tested through the comparison of the classified and graded result of the human expert (farmer) to the result of the system.

## 2. Review of Related Literature

Presented in chapter 2 is the review of related literature and studies which the proponent believes, has eloquent bearing to the present study. The proponents gathered relevant literatures which provide and help them to build the thoughts, views and information in developing the study. Based from the different facts obtained, the proponent constructed conceptual and theoretical frameworks.

It can be summarized that most of the proponents make use of single variable in their research. Methodology such as the artificial intelligence were used and was able to seen on the evaluation of the processed image. Also, most of the study used MATLAB. Most of the researches focused on the image processing through image segmentation, feature extraction and through RGB color space. Most of the researches make use of fruit as variable for experimentation because fruit has its unique features and these fruits are the common fruits which is in high demand in the production. Through the information and knowledge studied from the work of different researchers, the proponents can now create their own system as accurate and functional as those researchers' work. In this case, the proponent will develop the automated classfying and sorting system.

## 3. Conceptual and Theoretical Framework

This chapter provides an overview of the methods and steps used in developing the sorting and grading system. The purpose of this chapter is to present the Conceptual and Theoretical Framework, as well as the proposed design which is based on the knowledge obtained from the different related literatures. This includes, but not limited to tools, processes and equipment used in the design and development of the study.

### 3.1. Conceptual Framework

The study aimed to develop the automated classifying and grading system. It will be developed through the designs and smart fabrication. The proponents used visual representation like diagrams to show the step by step processes on how the system will be made. This diagrams will set as guide for the proponents' concept about the system. These visual aids was very helpful to them in conceptualizing and building the system.

Figure 1 shows the overall flow of the research study from beginning to the end. It was a simplified and detailed form of process where it includes subsystems for the design and development phase. The usual process begins from the conceptualization where a lot of research will be made. It covers the brainstorming and consultation to the experts. The proponents will now set their objectives to the chosen study where problem and the scope were identified. In the third blocks is the review of related literatures where these will set as the basis of the study. It covers gathering and analyzing the work of others as reference in creating own study. In research materials and methodologies, all algorithms, software and hardware system, component or equipment that will be used will be listed and discussed. In designing, it demonstrates the specification requirements to make the subsystems and the implementation of the design will be the phase of developing. Machine Vision system, Fuzzy Inference System, Sorting System and Grading System will be used in the design and development of the system. The System Testing comes next where the proponents needed to test the system to make sure that the functions are successful. After the enhancement and improvement of the system, it will now be finalize considering all the factors connected to it. Lastly is the implementation of the system where it is distributed and given to the user specially the farmers to achieve the objective of assisting them in the operation by giving them an automated system.

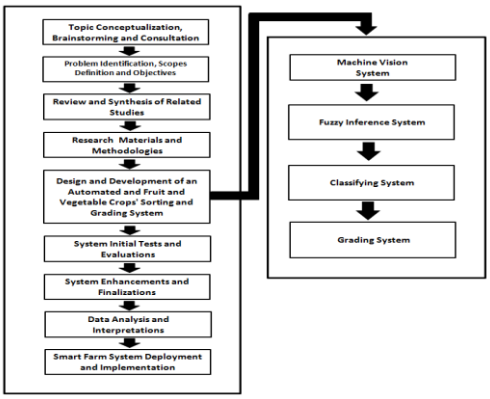
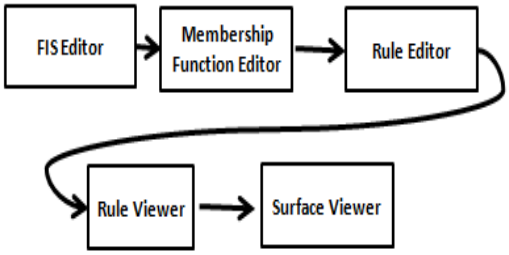



Figure 1. Method of Research

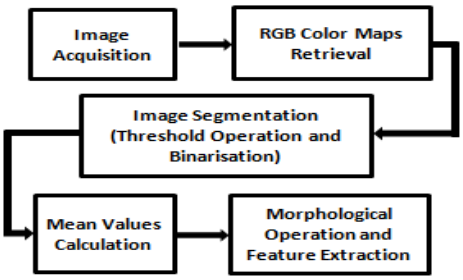
In Figure 2, the proponents elicits the detailed and simplified flow of the machine vision system using blocks. It shows 5 blocks starting on to image acquisition as the first step. It is the process of retrieving an image from the hardware based source. Next phase is to specify the primary colors as Red, Blue, and Green (RGB) color maps. It will be followed by the next two blocks which is considered as a significant blocks because of their crucial role. The blocks include Image segmentation and feature extraction where image will be pixilated into color black and white. Lastly is the Calculation of mean values from the obtained value in RGB color maps.

Figure 2. Machine Vision System

Figure 3. Fuzzy Inference System



**Block Diagram**




In the Figure 3 shows the five Graphical User Interface tools for the Fuzzy Inference System. These includes Fuzzy inference System (FIS) Editor, where it is composed of two types: Sugeno and Mamdani. Next is the Membership Function Editor for editing the input and output. After that is setting the rules in the Rule Editor and can be viewed in Rule Viewer and last is the Surface Viewer for the representation output. Through the MATLAB fuzzy logic toolbox, these five GUI tools was provided as a facility in fuzzy logic systems.

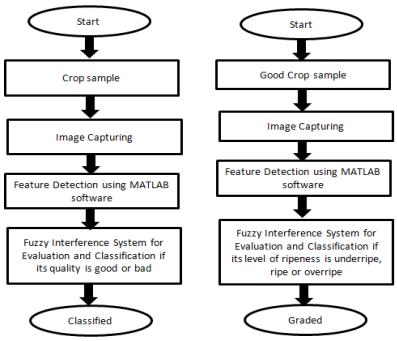



Figure 3. Flowchart For Classifying and Grading System

A detailed and simplified flow of process was provided in Figure 3. This shows how classifying and Grading will be done in simple process. The system will first start to classification process where good or bad quality will be sorted after it undergoes to image processing and FIS evaluation and classification. Good quality crops will go directly to the grading process where level of ripeness will be determine upon finishing the preceeding processes.

### 3.2. Theoretical Framework

#### 3.2.1 Fuzzy Logic Controller

Fuzzy Logic Controller is either be a software or a hardware. It is considered as a fuzzy code designed which function is to control something and it can be used in anything from the small circuits into the large frames. Fuzzy logic usually builds through the rules set by user-supplied human language.

Fuzzy systems was able to convert the set of rules to their respective mathematical equivalents. Through this, its function is to simplifies the work of the system designer and also the computer, and giving the results in highly accurate representations.

##### 3.2.1.1 Membership Functions

A fuzzy set is characterized by its Membership Function (MF). A Member Function is A function that specifies the degree to which a given input belongs to a set.

One type of the Membership Function is the Trapezoidal MF which is specified by a, b, c and d as the four parameters. Its equation is represented below:

$$\text{trapezoidal}(x{:}a,b,c,d) = \begin{cases} 0 & x < a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \dfrac{d-x}{d-c} & c \le x \le d \\ 0 & x > c \end{cases}$$

### 3.2.2 Fuzzy Logic Toolbox

The Fuzzy Logic Toolbox is a device that takes care of the fuzzy logic's issues. It can be used through the MATLAB software and does a good job of exchanging off amongst criticalness and exactness - which people oversee for quite a while. It also provides a Simulink Toolbox for scheming, analyzing, and simulating of the systems. The function of the toolbox is to control the procedures in developing and designing fuzzy inference system.

MATLAB technical computing environment used for designing systems was provided in Fuzzy Logic Toolbox containing different tools. The Graphical User Interface (GUI) which is a powerful tool for visualization purposes serve as a guide in different steps in the design of fuzzy inference system.

### 3.2.3 MATLAB

Matrix Laboratory (MATLAB) is considered as the easiest type programming language which is widely used for writing mathematical programs particularly for solving an algebraic and differential equations. It is an effective graphic tools that can bring images not only in 2D but also in 3D.

MATLAB software is composed of different tool boxes that is very functional for processing of image, signal processing, communications, smart grid design, optimization, control systems for industry and robotics as computational finance which is commonly used by engineers and scientists.

### 3.3. Proposed Design

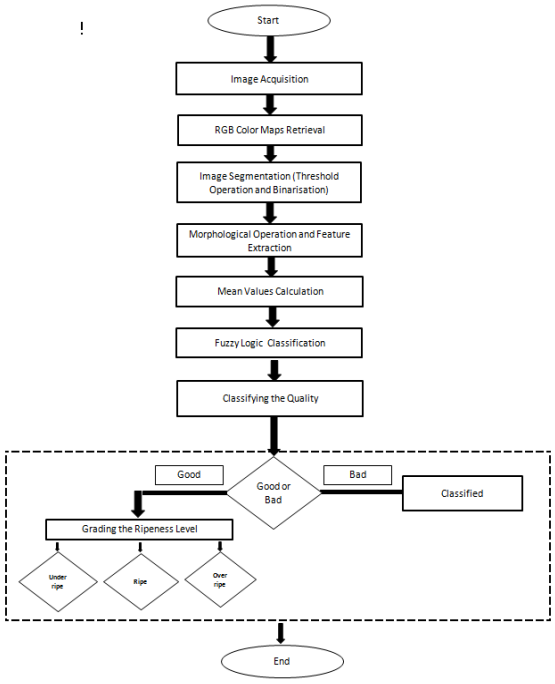
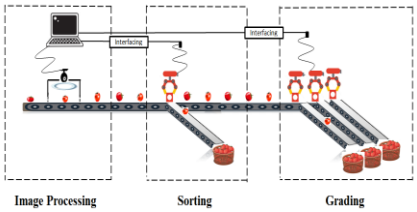



Figure 5. Flowchart of the System

The process flow of the system was shown in the Figure 2. It will start from capturing the image in a light cell as image acquisition. The machine vision system will now take over processing the image through retrieving the RGB Color Maps, Image segmentation where threshold operation and binarisation were done, then feature extraction and the calculation of mean values. After it undergo to the processing, the image will now be converted into binary of 0's and 1's and will serve as the input for the fuzzy logic classification and evaluation. Process will proceed to classification where it will be sorted to its quality whether it is good or bad. Only the good quality will now undergo to the grading system where the level of ripeness will be determined if it is under ripe, ripe or overripe.



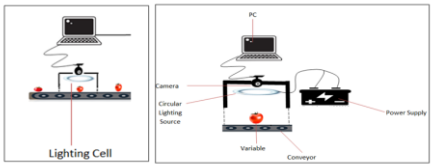



**Figure 5. *Proposed Design***

In this study, an automated classifying and grading system using Fuzzy Logic is to be develop. Figure 5 shows the visual representation of the proposed design of the system. It shows the overall process through the hardware that are interconnected to each process.

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