KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

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ANALYSIS AND AUTOMATION OF FRUIT PROCESSING SYSTEM

Supervisor
Assoc. Prof. Dr. Jolanta Baskutienė

KAUNAS 2016

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ANALYSIS AND AUTOMATION OF FRUIT PROCESSING SYSTEM

Final project for Master degree

621H73001 Mechatronics

Supervisor
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DECLARATION OF ACADEMIC HONESTY

/ /2016

Kaunas

I confirm that a final project by me, **Nikhil R. Rane**, on the subject " Analysis and Automation of Fruit Processing System" is written completely by myself; all provided data and research results are correct and obtained honestly. None of the parts of this thesis have been plagiarized from any printed or Internet sources, all direct and indirect quotations from other resources are indicated in literature references. No monetary amounts not provided for by law have been paid to anyone for this thesis.

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Nikhil R. Rane "Analysis and Automation of Fruit Processing System" *Master's* Final Project title supervisor assoc. prof dr. Jolanta Baskutiene; Kaunas University of Technology, Faculty of Mechanical Engineering and design.

Area of study and field: Technological Sciences, Production and Manufacturing Engineering

Kaunas, 2016. **69** p**.**

SUMMARY

This final project considers fruits processing automation development. The analysis of the different fruits processing systems is presented. The advantages and disadvantages of the fruit processing systems are analysed. The automation of the fruit processing plant is carried out into two distinct section of control using Programmable logic controller (PLC) and operator interface of the Supervisory control and Data acquisition system (SCADA). The prototype of the fruit sorting subsystem is developed and the algorithm for sorting of fruits depending on the size, colour and maturity of the fruit is developed. The results for the object recognition for specified fruit images on colour and size were developed by using Matlab. The calculations are made for the selection of conveyor system. The application of the image recognition is discussed. The conclusions of the work are defined and future developments of the system are proposed.

Keywords: *fruit processing, automation, control system, object recognition, image recognition, fruit classification, SCADA, PLC*

Nikhil R. Rane. Vaisių apdorojimo sistemos analizė ir automatizavimas Magistro baigiamasis projektas / vadovas doc. dr. Jolanta Baskutienė; Kauno technologijos universitetas,Mechanikos inžinerijos ir dizaino fakultetas.

Studijų kryptis ir sritis: technologijos mokslai, gamybos inžinerija

Kaunas, 2016. **69** p**.**

SANTRAUKA

Šiame baigiamajame projekte nagrinėjamas vaisių apdorojimo sistemos automatizavimo vystymas. Pateikta skirtingų vaisių apdorojimo sistemų apžvalga. Atlikta sistemų privalumų ir trūkumų analizė. Vaisių apdorojimo sistemos automatizavimas realizuojamas skirtingo lygio valdymo sprendimais: naudojant programuojamą loginį valdiklį ir duomenų surinkimo ir dispečerinio valdymo sistemos operatoriaus sąsają. Sukurtas vaisių rūšiavimo posistemio prototipas ir sudarytas vaisių rūšiavimo pagal spalvą, dydį ir vaisių sunokimo laipsnį algoritmas. Atlikti konvejerinės sistemos parinkimo skaičiavimai. Išnagrinėtas vaizdų atpažinimo pritaikymas. Suformuluotos projekto išvados ir pateikti pasiūlymai sistemos tolesniam tobulinimui.

Reikšminiai žodžiais: vaisių apdorojimas, automatizavimas, valdymo sistema, vaizdo atpažinimas, vaisių klasifikavimas, duomenų surinkimo ir dispečerinio valdymo sistema (SCADA), programuojamas loginis valdiklis (PLV)

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<table>
<tr><td>Approved:
Head of
Department of
Production
Engineering</td><td><i>(Signature, date)</i>

<i>(Name, Surname)</i></td></tr>
</table>

FINAL DEGREE PROJECT TASK ASSIGNMENT
MASTER STUDIES
Study programme: MECHATRONICS

The final degree project for the Master qualification degree is research or applied type project, for completion and defence of which 30 credits are assigned. The final degree project of the student should demonstrate the acquired knowledge and skills, ability to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final degree project of the Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies, correct language and ability to formulate proper conclusions.

1. Title of the Project

Analysis and Automation of Fruit Processing System

Approved by the Dean: 2016 May 3rd. <u>Order No. V25-11-7</u>

2. Aim of the project

To carry out an analysis of the current fruit processing systems and propose the automation solution

3. Structure of the project

- **o** Introduction
- **o** Literature review
- **o** P&ID layout of the original system
- **o** Development of the control part
- **o** Results for object recognition depending on the color and size
- **o** Conclusions
- **o** References

4. Requirements and conditions

Camera requirements PULNIX 6700, resolution 640*480 pixels, capture rate 60 frames/min.
Canny Edge detector algorithm for calculating the edges of the captured image.
DC Motor (L293D) 12V, 10/30 rpm, PLC for controlling and SCADA for supervision.

5. This task assignment is an integral part of the final degree project

6. Project submission deadline:

Given to the student

Task Assignment received   <u>Nikhil Ramdas Rane</u>
                                                (*Name, Surname of the Student*)   (*Signature,date*)

Supervisor

                                                (*Position, Name, Surname*)   (*Signature,date*)

Table of Contents

Nomenclatures

- **Abbreviations**

CBIR	Content-based image retrieval
PCB	Printed circuit board
GUI	Graphical user interface
RGB	Red, Green, Blue
IC	Integrated circuits
CCD	Charged coupled devices
IR	Infrared
NIR	Near infrared
CPU	Central processing unit
VGA	Video graphics array
TIFF	Tagged image file format
VFD	Variable frequency drive
PLC	Programmable logic controller
SCADA	Supervisory control and Data acquisition
CIP	Clean-in-place
P&ID	Pipping and instrumentation diagram

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Introduction

Fruit are major food products and key ingredients in many processed foods. They are a rich source of vital nutrients and constitute an important factor of human nutrition. Consumers present are more aware of the grandness of healthy foods and require food products with high nutritional value along with high standards of sensory characteristics. Thus, the processing has to preserve the nutritional value of the fruit, while also preserving its natural color and flavor [41].

Fruits are highly perishable, and about 20%–40% of the fruit produced are wasted from the time of harvest till they reach the consumers. To reduce fruit loss and improve final exam sensory characteristics of processed fruits, new or improved technologies have been applied to fruit processing [41]. Mechanical robotization is progressively getting essential in the sorting procedure since PCs or machines are equipped for taking care of tedious assignment rapidly and adequately. Along these lines machines are additionally able to sort natural products as per the evaluations without oversights. In this robotization framework, which includes mechanical structure what's more with gadgets portion independently, is intended to be utilized as a part of little horticultural commercial enterprises. There are a few motivations to need this machine as an answer for farming modern issues. These days, utilization of human power particularly in horticulture segment is basically and generally utilize. The following task describes the steps needed in the manufacturing of fruit juice concentrate.

Inspection conveyor → elevator → sorting of fruit → destoning and peeling → preheater → pulping → balance tank → standardization

Disadvantage of the present system-

- ➢ Mechanical systems are bulky
- ➢ They require man power to operate the system
- ➢ Less accuracy
- ➢ Degraded speed
- ➢ No fully automatic operation
- ➢ Hung chances of human error and mistakes
- ➢ Accuracy is less as controlling is done manually even in case of semi-automatic control

One of these undertaking goals is replacing labor with machine. Normally a great deal of human blunder happens during the procedure of fruit sorting. Subsequently this framework is proposed to minimize or defeat those blunders. Generally individuals can work around 7-8 hours for every day. Working more than this period now and again, makes the laborers lose their center and to focus at

work gets to be trying for them. Automation frameworks these days do overcome this issue and in addition the outlined framework produces proficient and high beneficial results. As a rule in commercial enterprises, planned machines are huge in size, in this manner are not convenient.

Aim: To carry out an analysis of the current fruit processing systems and propose the automation solution. To reach the aim it is necessary to solve the following tasks:

- **o** To perform an analysis of the current fruits processing systems;
- **o** To propose the automation solution for the development of the fruit processing system;
- **o** To develop a prototype of a sorting system;
- **o** To develop control part of the system;
- **o** To evaluate the results for object recognition depending on the color and size.

1. Literature Survey

Source of idea

India is an agricultural country; Economy of India depends on agriculture. Hence project for agricultural field will have big scope, decision was made to do something, which will be help full to automate some of agricultural activities.

Fruit quality has been a key issue to cultivators and retailers all through the historical backdrop of the business. The business sector for fruit quality has been becoming quickly in the course of the most recent decade, expanding the estimation of premium produce.

Therefore by modernizing the current project it will be helpful to measure the quality of the fruit and process them accordingly.

Survey

Recognizing patterns, especially visual and sound patterns form a part of recognition system that is an important field of computer science [1]. The recognition system is central to optical character recognition, handwriting recognition and voice recognition. The methods involves from areas of machine learning, statistics, etc. Quintessentially, it has applications in text classification to recognize different type of texts like the spam and non-spam E-mails, speech recognition for particular purposes like translating various languages to English[2], handwriting recognition for postal codes usage, or the techniques of face recognition along with digital images that are input to the pattern recognition systems[3].

In recent years, for recognition and classification of agricultural produce like fruits and vegetables different types of image analyzing techniques have been developed.

The fruits recognition system could be applied as an image contents descriptor which is able to describe the low level visual features or contents of the fruit images for the CBIR system [4]. Color-based and shape-based are the popular analysis methods for classification and recognition of two dimensional (2D) images. Here the problem of having similar color and shape values for different images. Therefore, this system lacks robustness and effectiveness required to differentiate fruits images accurately.

Hence, a proposed recognition system for 2D fruit images that compromises of color, shape and size is develop to get more accuracy of the recognition result. A 2D query image is provided to a system that extracts its features values like color size and shape and computing the feature's values so as to compute the distance between the computed values and stored standard values for particular fruit type. Thus, fruit recognition system is an innovative and important system that has evolved due to virtue of various motivations. Likewise, the system in consideration researches on

the pattern recognition such as fruits spherical pattern recognition and proposed system is developed to research on pattern recognition system, especially on fruits spherical pattern recognition and sorting system. Here, a pattern recognition system compromising of color size and shape is designed to perform sequential pattern classification.

This method is useful in sorting of other objects and recognition issues. The software has wide application in the fields of image retrieval, education and plant science research. Some of its applications are as follows: Food products recognition in supermarkets for labeling and billing. In food processing industry to remove the defective fruits. It is used in plant scientists for understanding morphology variation of fruit shape to further understand the molecular and genetic mechanisms of fruits. In the field of education, enhanced learning for small kids and Down syndrome patients.

The processing of nutrient can be defined in many different ways. A review of many traditional books dealing with the topics of nutrient processing indicates that the definition is closely related to the merchandise or commodity being processed. Many of the traditional definitions stress the relationship of nutrient processing to the preservation of nutrient, and this dimension still represents the ace most important intellect for processing. A simple definition of food processing is the conversion of altogether stuff or factor into a consumer food product. A more complete definition is found in Connor (1988) [5], where "commercial food processing" is defined as that branch of manufacture that offset with raw animal, vegetable, or marine materials and transforms them into intermediate foodstuff or edible products through the application of labor, machinery , and scientific knowledge. This more complex definition clearly indicates the kickoff and end points for the food manufacture, as well as the stimulant required to achieve the desired resultant [37].

The improvement of vision frameworks started during the 1970s, taken after by across the board mechanical application during the 1980s. Color has been an awesome help in recognizing objects for some a long time. It is regularly valuable to disentangle a monochrome issue by enhancing difference or partition. The procedure of color grouping includes extraction of helpful data concerning the properties of article surfaces and finding the best match from an arrangement of known portrayals or class models to actualize the acknowledgment task [4].

Moreover, most producers incline toward machine vision frameworks that give rapid, 24-hour, repeatable, and solid operation, instead of human assessment, which has a high percentage of error because of diversion, disease and different components that build the rate of disappointment because of more working hours. To overcome such challenges, a visual-based color arrangement framework is presented. This framework is broadly utilized as a part of the modern assembling, as it can decrease reliance on labor and subsequently expand production. Essentially, a machine vision

framework performs four fundamental steps: picture catching, processing, analyzing and interpreting. The physical components in a vision framework comprise of a camera or sensor, lighting, a computer, and programming. A camera is utilized to take the photo of the object being investigated. Lighting is expected to enlighten the article, so that the picture taken by the camera is enough uncovered. The PC is a key component of the machine vision framework; a quick system will decrease the time required for picture handling. Finally, machine vision programming is utilized for making and executing schedules, preparing approaching picture information and giving a convincing result [5].

Various specialists have performed concentrates on looking at the color attributes of wood. They have concentrated on color estimation frameworks and how they can be connected to better control the color sorting process in the assembling of hardwood items [5]. Vision frameworks are likewise utilized as a part of reviewing Printed Circuit Boards (PCB) containing electronic segments to check appropriate segment determination and situation. Another use of color machine vision is in the automotive industry, where parts, for example, side-view mirrors must be collected on the right car body through color confirmation. Different analysts have created machine vision frameworks for the color sorting of leafy foods [6].

Programming development is exceptionally vital in this color characterization framework. The MATLAB Graphical User Interface (GUI) is utilized as a part of this study as the centerpiece of the framework in perceiving hues and showing the outcomes. The principle capacity of the project created here is to ascertain the histogram of Red, Green, and Blue (RGB) hues in the edited zone of the captured picture and compute its mean qualities. The project shows the mean qualities in both decimal and hexadecimal. The last result is then appeared on the screen [7].

Color detection study has an application in classification of fruits and vegetables as ripe and unripe. Fruits like oranges tomatoes, bananas, papayas and mangoes will show detectable change in color as they mature. The majority of the fruits and vegetables are green when they are raw and turn yellow or orange or red once matured [7].

Appearance based classification of fruits include parameters like size, color, shape, etc. These parameters can be used to determine their quality and classify them. Color is a major parameter indicating ripeness, defects, etc. in the fruits. Presently, the inspection of sizes and color of many food products is relied on human vision. However, human visual inspection has a disadvantage of adapting to slight changes in color and the effect of the background on the perceived color and color intensity. Thus for uniform decision, machine vision technology based on image analysis using color has proved to be the best technique to determine quality of fruits [1].

Since the human inspection is subjective, time consuming and prone to errors machine vision-based fruit sorting systems are preferred owing to its easy handling, cleanliness, and better

accuracy. In these systems images captured by camera are processed using image processing software for analyzing the fruit quality one of the many accomplishments of image processing techniques is non-destructive analysis of fruits for easy determination of color and size [2].

Filiberto Pla et al.[3] have created an embedded system, using personal computer (PC) architecture that does not require user interference. Values of Red- green-blue (RGB) and infrared (IR) are used to sort fruits based on size and color using a machine vision unit that is part of distributed control system. Distributed control system has different machine vision unit integrated together with user interface. They have used commercial progressive scan color and IR cameras that had asynchronous reset facility. They have computed the size parameters for fruits in terms of their maximum, minimum, or average diameters and color classification using classification rules provided by a binary decision tree.

Object Recognition

One of the major applications of image processing and computer vision is object recognition. The term "object recognition" is often is used in broad sense, so it is important to take an insight to understand its meaning. One of the common features of many techniques in image processing is to analyze one or more images to recognize the objects present in it. This feature gives them some knowledge about the appearance of the objects to be found (the model, which has been created in advance). One of the special cases is that the model database contains only one object class and so the task is much easier to decide whether an instance of this specific object class is present and its location. Other features that need an attention is the specific characteristics of each application. So as to meet these particular necessities, rich assorted algorithms of calculations has been proposed throughout the years.

The surveys written by Chin and Dyer [9], Suetens et al. [18], or Pope [15] give detailed and systematic overviews. Likewise, many others have also contributed to these surveys. But these surveys do not cover some areas researched in last decade e.g. descriptors-based recognition. Reports focusing on the usage of descriptors can be found in [16] or [13]. Mundy [12] has written a chronological overview of the topic by summarizing evolution in mainly geometry-based object recognition during the last five decades. Reading this surveys or papers is difficult to read for a novice person in this field. There are books related to object recognition like the books of Grimson [10] or Bennamoun et al. [8]. However, I feel all this work does not cover all the aspects of the field. Also, it is insufficient to explain the armatures at the same time. Papers and articles written either throw light on specific topics or written in brief. There are collections of original articles (e.g., by Ponce et al. [14], which assumes that the reader can understand specific knowledge by himself. The book written by Jähne [11] gives introduction into generalized field of image

processing along with previously mentioned supplementary steps like edge detection, etc. An excellent overview of the superordinate image processing from perspective industrial application can be found in the book of Steger et al.[17].

Areas of Application

Outlining the spectrum of applications of object recognition is one way of demonstrating the diversity of the subject. It includes industrial applications (more commonly, the term "machine vision" is used), security/tracking applications, also searching and detection applications [40].Some are mentioned below:

Position measurement: It is used mostly in industrial objects. The information about the position is useful in production environment for placing parts or transporting, gripping and processing on assembly line etc. For example, it is crucial to locate components like ic's prior to placing them on PCBs (printed circuit board) As an example, it is necessary to accurately locate electrical components such as IC's before placing them on a PCB (printed circuit board). This is done to ensure proper soldering for all connections for the production of electronic devices (e.g. TVs, mobile phones, laptops, etc.). The object pose refers to x-y position of the object along with its rotation and scale.

Inspection: one of the classical usages of machine vision would be for quality control in production environments. By inspecting the surfaces of industrial parts one can detect the defects for e.g. inspection of welds or threads of screws. This requires determining the position of the parts in advance thereby involving object recognition.

Sorting: It is used in various applications like for example, in postal automation services parcels are sorted depending on their size. Prior to this, identifying and localizing of the individual parcels is done.

Counting: The number of occurrences of a specific object in an image is required for some applications, for e.g. In molecular biology the number of erythrocytes depicted in a microscopic image might be needed by the researcher

Object detection: The scene image containing the object to be identified is compared to a model database that has information of all objects [40].

Color based Sorting of Fruits using Machine Vision System

Sorting fruits depending upon their color, shape, size etc. can be done. Quality of fruits is determined using these parameters. Color indicates ripeness, defects, freshness etc. At present, human vision is used to inspect food products using parameters like the color and size etc. But this has human limitation as human eyes cannot distinguish slight changes lie in color after prolonged

observations. Moreover, the background of the object and color intensity. For consistent decisions, image analysis using color is used in the machine vision technology to determine quality of fruits is one of the best techniques [19].

Since the human inspection is subjective, time consuming and prone to errors machine vision-based fruit sorting systems are preferred owing to its easy handling, cleanliness, and better accuracy. In these systems images captured by camera are processed using image processing software for analyzing the fruit quality. One of the many accomplishments of image processing techniques is non-destructive analysis of fruits for easy determination of color and size [20].

Machine vision system having parallel software and hardware architecture is developed to sort different types of citrus fruits in real time by Aleixos et al.[22]. This is done by examining external quality features of the fruits like the color, size. Also, the external defects are captured using a multispectral camera compromising of two charge coupled devices (CCDs) for color and near infrared (NIR) information. Sirisathitkul et al. [23] conceived a robotized orange development sorting framework utilizing color evaluating. A color CCD camera for image acquisition and a computer for image processing formed part of this system developed.

Tao [24] devised a technique to classify fruits based on color by extracting a single hue value from red, green, and blue components measured on the fruits. Later, this value was compared to user defined and programmed grading criteria. Lino et al.[25] used a setup consisting of a CCD camera and a personal computer for analyzing color of tomatoes based on RGB values of camera. Gaffney's [26] system was able to distinguish specific variety of oranges based on color using a single wavelength band of reflected light at 660 nm. This technique was able to differentiate light orange, normal orange and green fruits. Slaughter and Harrel [27] developed a method to recognize mature oranges. To serve this purpose, they captured color images with the help of camera and artificial lighting.

Using CCD cameras and image processing, the size and color based sorting of citrus fruits was developed by Ahmad et al.[28] and Khojastehnazhand et al.[29]. Along with this, Khojastehnazhand et al.[30] developed an image processing technique for estimating mass, volume, diameter, and surface area of citrus fruits using two CCD cameras. Although grading systems provide information such as color, size, defect, shape and internal quality, only size and color are the foremost features for accurate sorting of citrus fruits such as oranges, tangerines, lemons, grapefruits etc.

2. Analysis of current system

The complete fruit processing system is explained in the fig.1. The figure clearly indicates the flow of the process. In the first section of feeder conveyor the fruit which is to be processed is placed on the conveyor panel. The fruit is then processed for the next step of sorting technique which is at presently manually done in the industry.
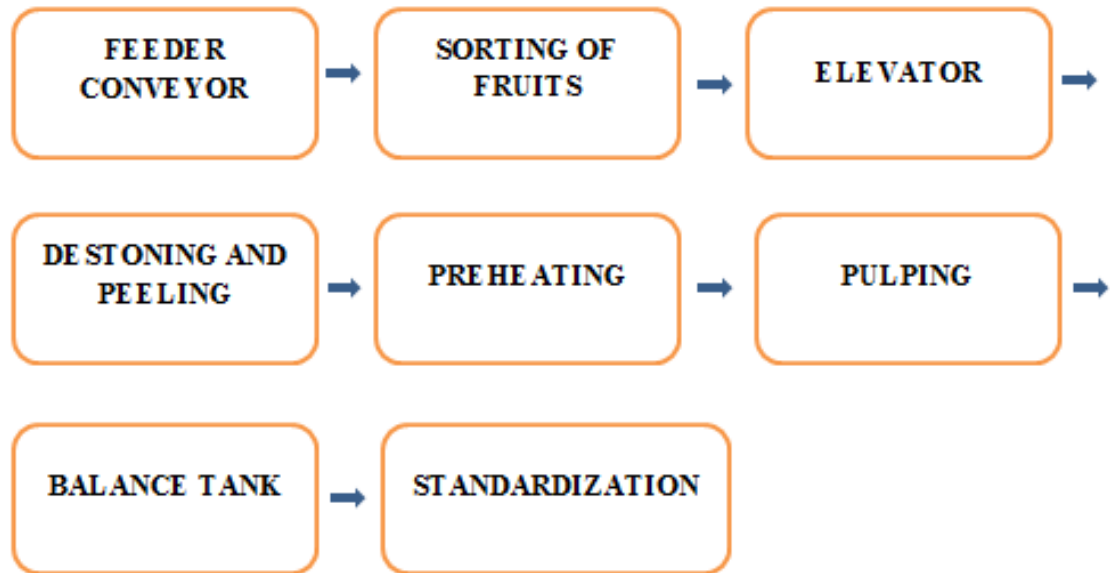

Figure 1 The complete fruit processing system

The sorting of fruit indicates the selection of fruit on the basis of parameter's like the color and size of the fruit and it is carried out by the labors working in the industry. The quality of fruit is decided manually, it has various barriers such as undesired way of handling the fruits, boredom, lack of sight; parameters for quality may vary from person to person. In short we can't get the good quality fruit. After the sorting of fruits is done the fruits are processed on to the elevators for the next step of process. The elevators the fruit is then processed in the destoning and peeling section. In that section the destoning of the fruit is done, along with it the peeling of the fruit is also performed. When the peeling and destoning of the fruit is completely done it is then processed to the preheating section. The preheaters are the type of process where the fruit is undergoing some heating techniques before it is processed to the pulping section. Then after the pulping of the fruit is performed it is transferred into the balance tank where the concentration of the fruit is checked according to the requirements. Then the fruit is processed for the standardization.

3. Pipping and instrumentation diagram (P&ID) of the original system

The plant is consisting of 4 lines in the production process. All the 4 lines are connected in a crosswise manner but it is to be done manually. Each section is separately connected manually to complete the flow of the process. For this process a number of workers are required. The operator has to go personally to connect the sections and have to personally go and use the manual control panel for operating the pump, solenoid valves and speed of the pump through potentiometer. The selection of line algorithm is necessary because of the process line has to be maintained regularly. The clean-in-place (CIP) is also required to be done regularly. In this process the cleaning of the pipes are done internally without de-assembling the plant. So at that time the production should not be affected or stopped. So when the particular section of any line is under maintenance or cleaning we can select the other lines without having any delay in production. While selecting the first line to start the production the operator has the freedom to choose any section and any line to start. By doing the cross selection method it improves the utilization of plant of production. For connecting the lines we use the flowverter panel. By using this panel we can connect different line with each other. There are some disadvantages for doing the process manually and the disadvantages are the cross section of the process is done manually by the operator intelligence. The scope of error in this manual process is more because if the operator makes any mistake in connection of lines the complete production will have to undergo a huge loss. And the food processing plant demands for least wastages and errors. If we have the manual selection a large number of workers will be required to manage, control and supervise the production plant. So to overcome all the human errors and to increase the production we are proposing algorithms, evaluating the controlling devices and developing the automation control with the help of PLC and supervising the control layer by using SCADA in the next sub section.

The fruit processing plant is mainly having 4 process lines. These process lines are all manually operated. These lines are working in the cross wise manner which is manually operated which means if a fruit is placed on the conveyor belt of line 1 the complete processing of the fruit will take place from the section connected by the operator according to the availability.
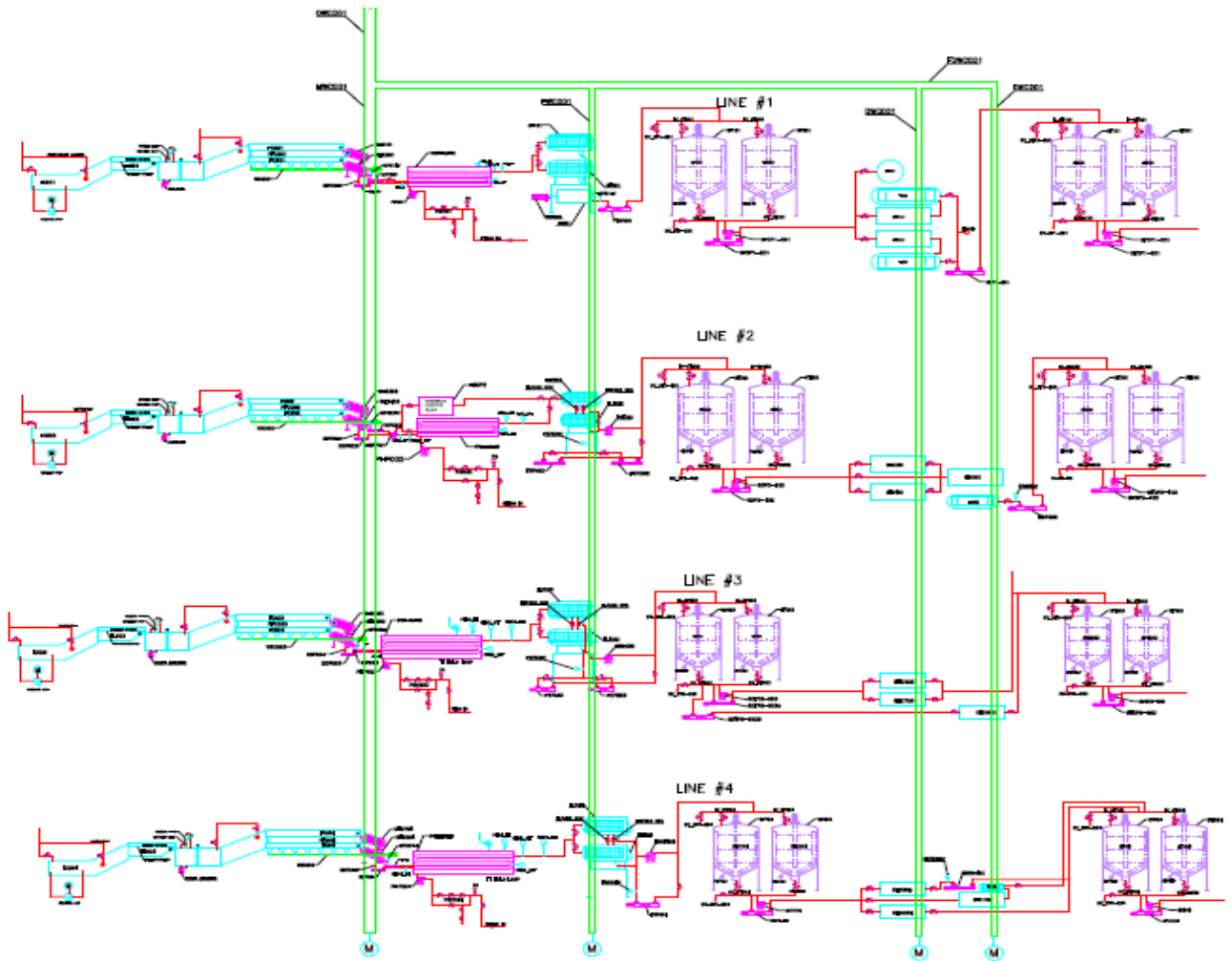
Figure 2 Line Selection view of the plant

The start and stop process of inspection line is done manually. In the next step of sorting of fruits all the fruits were sorted manually. There were workers assigned to do the sorting of fruits. Sorting of fruits manually on the parameters of its size and color and on the maturity of the fruit. So the sorting of fruits can have some human errors due to lack of sight. Then these sorted fruits were processed further through the elevators for the destoning and peeling of the fruits. The peeling of the fruits is done only for the banana and the remaining fruits are processed for the destoning part. After the destoning section the fruits are processed for the preheating section which is useful in the process before the pulping of the fruit is taken into consideration. Then the final stage of the processing is the balance tank and the standardization.

3.1 Preliminary concept & control part of the system

Line selection view of the plant

The pre-developed P&ID layout of processing plant shown in the below figure 2 and the development of the manual operated plant is designed in the Rockwell Automation Factory talk

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view, SCADA application under the supervision of the experts. The preliminary design indicates the complete process of the plant which is controlled manually and the complete system is developed into an automation system to achieve the goals in my current thesis are shown below in the figures 3, 4, and 5.

➢ A complete overview illustrated in figure 3 in the previous main section resembles a P&ID (pipping & instrumentation) diagram for the fruit processing plant.
➢ P&ID is the base for developing SCADA screens that will form the supervisory layer above the control layer associated with PLC.
➢ The placement of motor, valve, level indicators in every section of preparatory, preheater, pulper of fruit, balance and standarilization tanks are clearly mimicked in this diagram.
➢ In short this is the blue print for the SCADA screen development and PLC automation method.
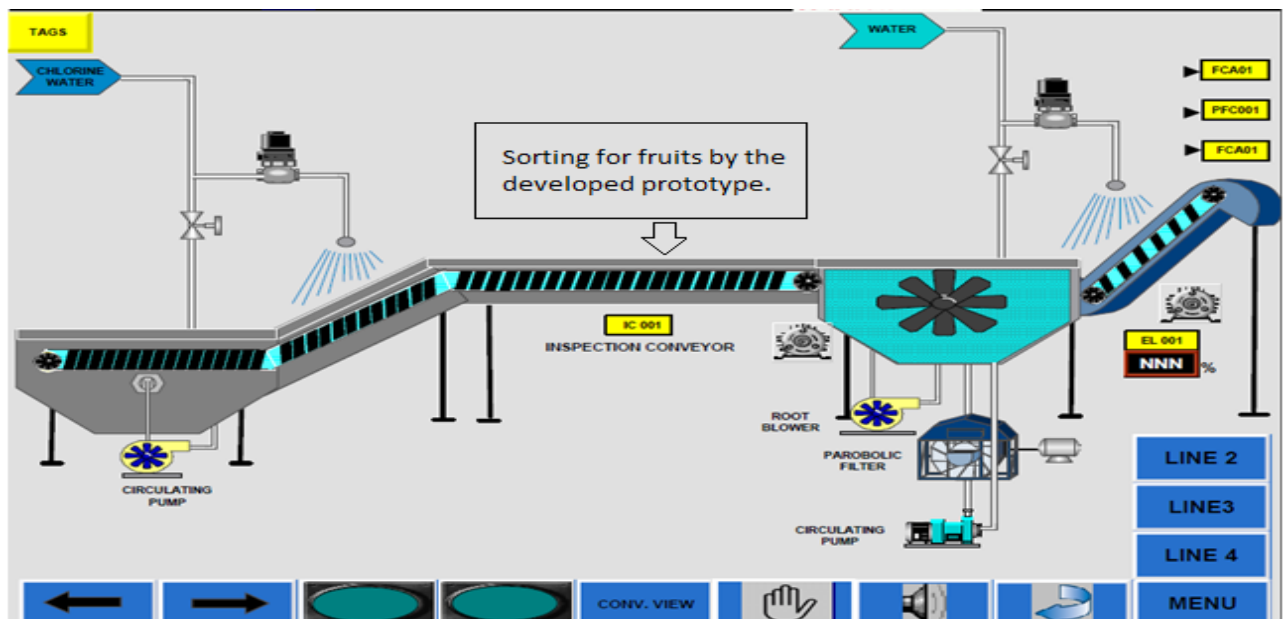

Figure 3 (section 1) Layout of the line consisting with inspection conveyor, sorting assembly, and elevator

➢ Preparatory line section is shown in figure 3 comprising of inspection conveyor and elevator section with standalone sorting mechanism.
➢ The screen is developed in Rockwell Automation Factory Talk View SCADA development environment for panel view 1500 (15" display) which is a touchscreen industrial PC.
➢ The figure 3 shows replica of preparatory section from figure 2. The display is mimic of actual operation of inspection conveyor and elevator with real-time indication of motor's status, i.e. running or stop with color representation red(stop) / green(running).
➢ The display comes with interface for setting speed for elevator "EL001"through input number pad.

> ➢ The screen incorporates various buttons for interaction with the actual process. Navigation button to switch to other screen. Auto/ Manual button to switch section, Auto or Manual operation.
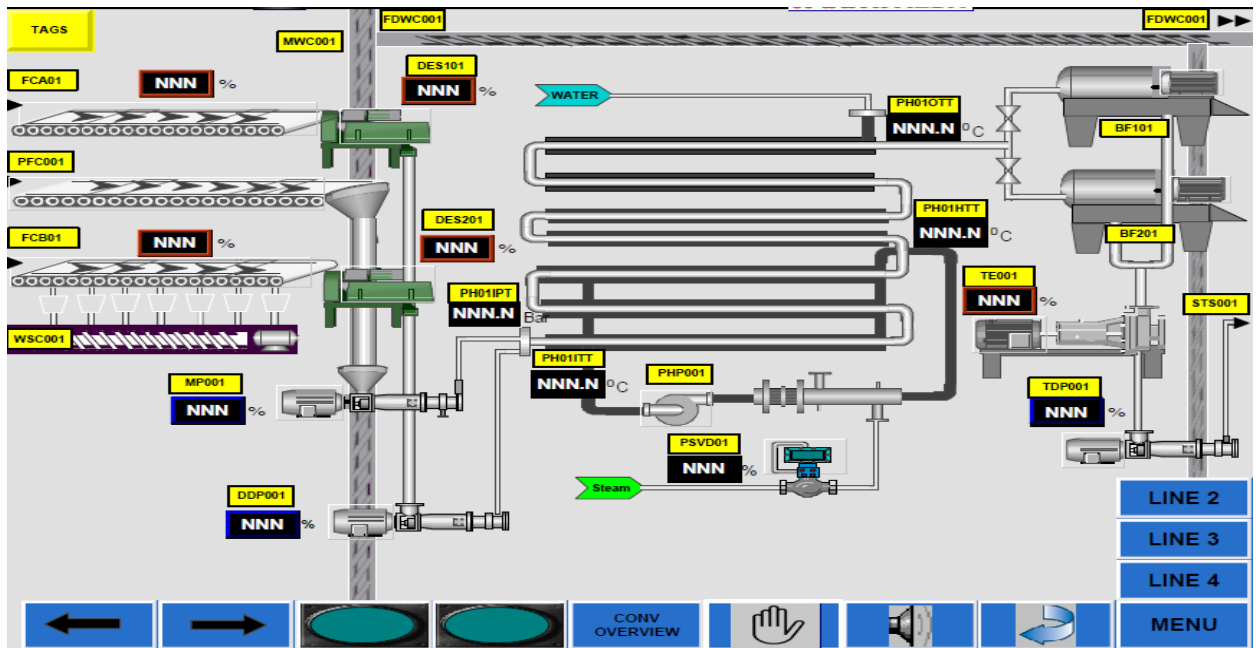

Figure 4 (section 2) Layout of the line consisting with conveyor assembly, destoning & peeling, preheaters and balance tank

> ➢ Figure 4 is the mimic for the forward conveyor and preheater section and pulper section.

> ➢ MP001 (Mash pump), DDP001 (Destoner discharge pump), DES (destoners), TDP001 (turbo discharge pump) have interface for speed control for VFD controlling these motors.

> ➢ Similar to figure 3 same standard has been followed for navigation and Auto/ Manual button.

> ➢ This section mimics the preheater heat exchanger unit that gives an overview of product temperature control. A detailed view of the P&ID control for preheater is developed in the next section in figure 5.

➢ Animated view for balance and standardization tank is shown in the above figure 5.

➢ Tank cut section is shown in figure 5, provides sanity in visualizing level of product in the tank with a percentage indicator of that tank.

➢ Every tank has a starter mechanism with motor that can be set Auto/ Manual by the operator that is exclusive of auto/manual of other production activities.

➢ Screen follows the same template of buttons like other section on button of the display.
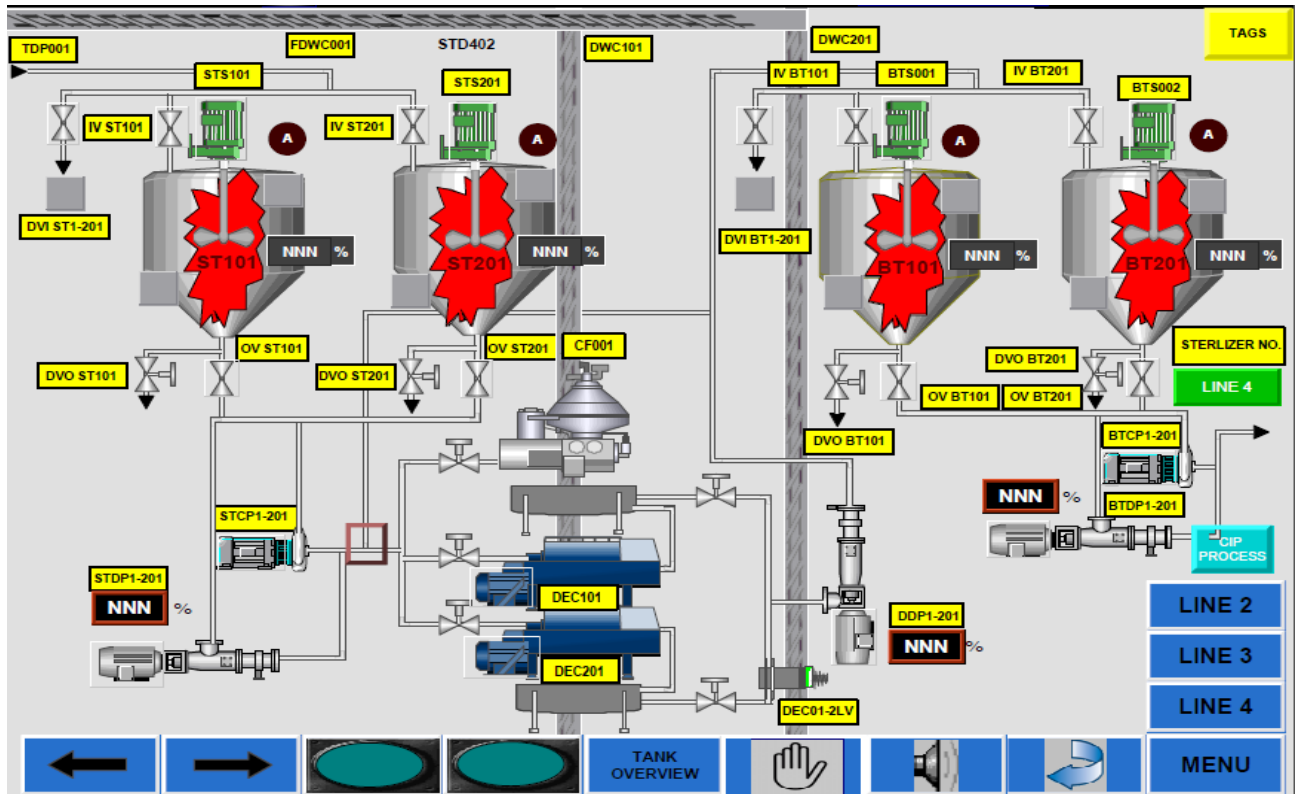

Figure 5 (section 3) Layout of the line consisting with cut section of standardization tanks along with the valves and piping connections

3.1.1 Fruit and production setup matrix

The method describes graph theory approach where graph is set of vertices and edges were formulated in this scenario of representing the electrical grid network. The elements of the grid network that includes the breakers, Buses and lines were assumed as nodes or vertices, the edges will eventually represent the connections that actually go through the topology.

Line selection (path selection) is the important part in any production line up. The matrix (view) of line selection process is the developed process which can be used in the manufacturing plant which is shown in figure 6. The given line set up is having various elements in it which has to perform according to the desired process. Each block has its own section which is pre-defined and

the selection of them is done by the user according to the necessity of the process. The figure shown below is the overview of the selection panel on the HMI screen.


Figure 6 Development of the plant using Adjacency list by applying crosswise method

But it should also be in a sequential flow as when the previous step is performed then the next process to start on. As in the line panel the first section is fruit which means it is on the conveyor assembly. Then the next part is preparatory line in which path of the fruit is decided. Preheater, pulper finishers, standardized tank, balance tank, sterilizer are all the paths from which the initial fruit has to pass for completion of the process. Previously the complete path process was manually operated which means we have to manually ON/Off all the steps for the process to get completed. As we can see the complete line selection panel is consisting of 4 rows and 6 columns.

For example, if the process is started and the conveyors are switched ON, we have to manually turn ON the preheaters after specific time and have to keep it ON for the limited time frame. We cannot keep it switched ON continuously as it will harm the production. So it was very important to turn it ON/Off when it is in process and when it is not in process. So as for preheaters we have to take into consideration all the individual elements of the process. Secondly if one path is in process and remaining 3 paths are not in process but still we have to follow the same sequence as the paths are not interconnected. This leads to wastage of time and it affects the production output. Hence it was necessary to modernize the complete plant and bring automation in to the manufacturing process.

To modernize this plant we can interconnect all the selection elements to each other. Its means all the elements i.e. 24 elements are interconnected to each other. The purpose of modernizing the process is to save the time, energy and labor work which is required to control the complete process. We can implement the modern techniques and solve all these problems. By using PLC automation we can control all the elements and we can decide which path to select and what to select according to the availability of the path. We can implement the above process by using adjacency list.

For example, when the fruit is processed on conveyor belt and all the elements are interconnected and the path for the second line is free then we can select the path according to the availability. For all the elements there is a discharge pump which is an indicator for the next element to get started. We have to select the path as we want on the HMI and all the connections are internally executed and the PLC logic plays an important role in the automation. By using the PLC logic we can control the path and we can reduce the human errors. In the adjacency list all the elements are interconnected to each other and we decide the path which we want to select. One such example of adjacency list is as follows.
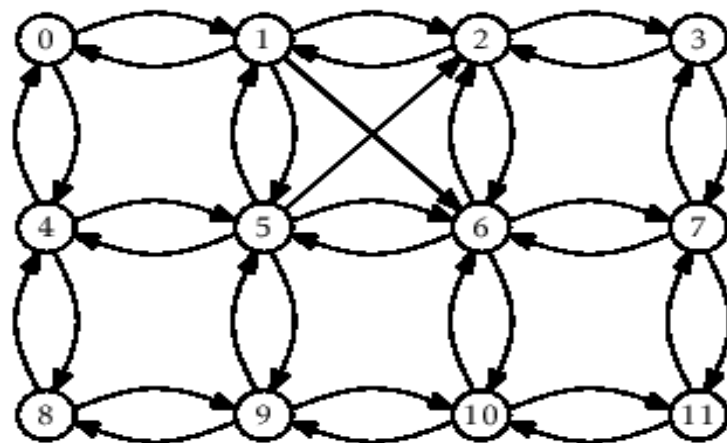
0	1	2	3	4	5	6	7	8	9	10	11
1	0	1	2	0	1	5	6	4	8	9	10
4	2	3	7	5	2	2	3	9	5	6	7
	5	6		8	6	7	11		10	11	
	6				9	10					
					4						

Figure 7 Graph and its adjacency lists

We can also select the direct line for the process. As the elements are interconnected to each other and if we want to use the same line for the process we can select the line wise selection option which will auto select the by default line but if we want to choose the line then we can use cross selection and choose which line to be used and which elements to be used from which line.
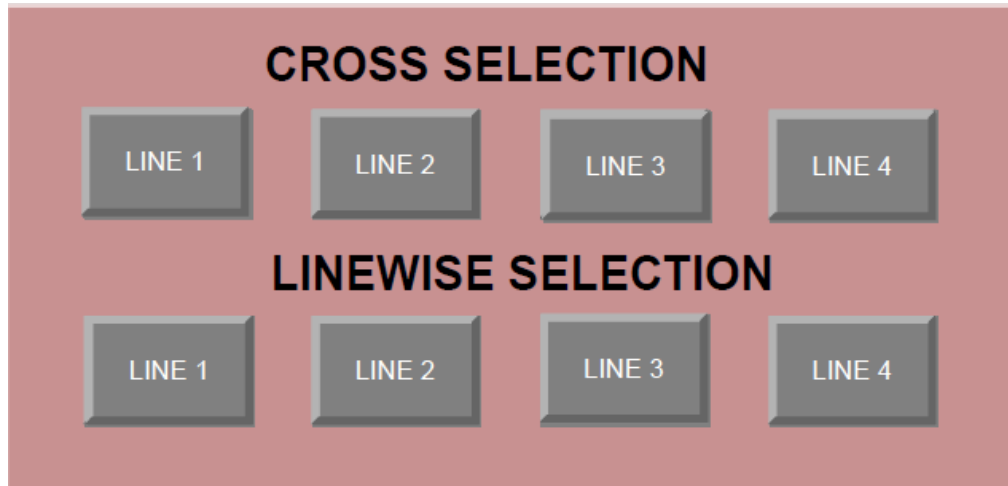

Figure 8 Line selection pattern

3.1.2 Application of Graph Theory

A graph is a set of edges E and Vertex V, i.e. G = (V, E). Edges E are lines connecting the vertices V and form an unordered pair of such vertices also called as union. Depending on the type of connections, order and size are important parameter for any graph, order being the number of vertices V and the number of edges constitutes the size of the graph.

Finite and Simple Graph

A graph with limited number of nodes is called as Finite Graph. A graph with no edges terminating on self-vertex and no parallel edges or connections to same connected vertex is an indication of Simple graph. Basically, a simple graph is one which has degree which a one connection to the connected vertex.

Similar approach is adopted in representing the Syslab grid. A vertex is represented as Breakers, Buses, Loads and Lines satisfies simple graph condition. In electrical connection having a multigraph approach is certainly unnecessary as the physical connection always remained to be singular.

Undirected Graph

Graphs are also classified on basis of the connected edges. If the edges connecting the nodes have a direction from source node to target, then the graph is called as Directed graph. The graph with bidirectional connection or one in which the direction of the connection is of no concern then it is undirected graph. As representation of Syslab Network is concerned the direction of the

connection plays no significance in visualization. Visualization of the Syslab topology is concerned only with the connected components in any order.
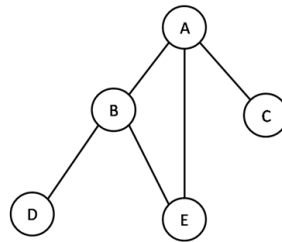

Figure 9 Undirected, Simple and Finite graph depiction [35]

The Fig 9 shows clearly mentions an undirected graph with 5 nodes, a finite nodes with directionless edges. Each pair of the connected nodes has a single edge which makes it a simple graph.

3.1.3 Sub graph Enumeration

Consider a Graph G with vertices V (G) and E (G) and another graph H with vertex and edges V (H) and E (H). Now Graph H is considered to be the subgraph of G only when V (H) is subset of V (G) and E (H) is a subset of E (H). In reverse way Graph G is super graph of H.

Identification of the nodes and links in the super graph is the objective of this application, i.e. finding the Subgraph elements from the status of active grid status is called subgraph enumeration. In a goal to achieve this objective, it was equally important to identify the elements with respect to subgraph number. In this way the numbering the identified subgraph will be vital information for knowledge of active topologies developed during the specific time.
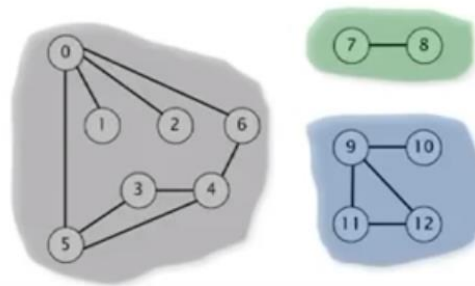

Figure 10 Illustrating connected components (CC) of a graph [36]

Table 1 Adjacency List of connected components

CC no.	Vertex No from Fig						
1	0	1	2	3	4	5	6
2	7	8	-	-	-	-	-
3	9	10	11	12	-	-	-

The Fig 10 shows an example of three connected component graph with a finite nodes in each of them. For the same subgraph the adjacency list of the subgraph were computed in table a with every node having a separate list of connected nodes or vertices.

3.2 Equipment and method for system automation development

Evaluating the controlling devices and evaluating the sensory feedback

We have to calculate the number of input/ output devices from the P&ID data flow of the complete system. The complete P&ID flow of the system is attached in the appendix. By observing the flow of the system and the controller used in it the input/output sensory feedback can be evaluated of all the controlling devices required to make a manual system to automatic system.

A small part of the list of controlling devices is mentioned below and the complete list of controlling devices is attached in the appendix. The sensory feedback for the controlling devices is also mentioned in the list of details of the controlling devices.

Table 2 IO-list-as-per-panel with-equipment-tags

	Equipment tags	Sub Equipment	Sub Equipment	Digital output	Digital Output	Analog Input	Analog Output
Line 1	EL001	Elevator L1	Start/ Stop	-	1	-	-
			Feedback	1	-	-	-
			Set VFD Speed	-	-	-	1
	IC001	Inspection Conv L1	Start/ Stop	-	1	-	-
			Trip Alarm/ Feedback	1	-	-	-

The above mentioned table is a small part of the list of controlling devices required in the complete system which have to be controlled form manual system to make it an automatic system.

In the line 1 section there are sub equipment's like elevator and inspection conveyor and many more which has different sub equipment. The elevator and inspection conveyor are the types of motor and for the motor the sensory feedbacks are evaluated accordingly.

The motor which is used for elevator has the different sub equipment's like start/stop, feedback and variable frequency drive (VFD) speed. The sensory feedback control for the motor includes start/stop, feedback and VFD for speed. As the start/stop is a digital output it can start or stop the motor when it is activated. So as the feedback is the digital input which the motor receives from VFD. Variable frequency drive is a used to drive the speed of the motor. The speed of the motor is

directly proportional to the frequency of the incoming signal. The analog output drives the VFD speed.

Setup a control which is regulated by specific centralized controller through PLC

- **Programmable Logic Controller (PLC)**

A programmable logic controller is a computer plan for utilized as a part of machines. Not at all like computer, it has been configured to work in the mechanical environment and is furnished with exceptional I/O and control programming language. Many industries use the abbreviations for these devices as PC, which can be confusing as it is also the abbreviation for personal computer. There most of the manufacturers prefer using the abbreviation as PLC, which is an abbreviation for programmable logic devices.

At first the PLC was utilized to replace relay logic, however its perpetually expanding range of capacities implies that it is found in numerous and more complex application. As the structure of the PLC depends on the same standards as those utilized in the computer engineering, it is fit for performing relay switching task, as well as likewise other application, for example, checking, figuring, comparing and processing of simple analog signal.

Programmable controller offers a few points of interest over conventional relay control. Relays must be hard-wired to perform a particular function. At the point when the framework prerequisites change, the relay wiring must be changed or adjusted, which requires time. In extreme case, for example, in robot/automation industry, complete control boards must be supplanted since it is not financially feasible to rewire the old boards with every model changeover. The programmable controller has wiped out a lot of hand wiring connected with traditional relay control circuits. It is small and in costly contrasted with equivalent relay- based control frameworks. Programmable controller likewise offers solid-state reliability, lower power utilization and simplicity of expandability. In the event that an application has more than half a dozen relays, advisable to introduce a PLC-Simulating a hundred relays, clocks and counters is not an issue even on small PLCs.

The advantages of PLC:
- ➢ Smaller physical size than hardwire arrangements.
- ➢ Easier and quicker to roll out programming improvements.
- ➢ PLC has coordinated with diagnostics and override capacities.
- ➢ Diagnostics are centrally accessible.
- ➢ Application can be quickly reported.

➢ Applications can be copied quicker and less expensive.

- **User Interface**

PLCs may need to communicate with individuals with the end goal of design, alarm reporting or regular control. A Human-Machine Interface (HMI) is utilized for this reason. HMI's are additionally referred to as MMI's (Man Machine Interface) and GUI (Graphical User Interface). A straightforward framework may utilize buttons and lights to connect with the client. Content presentations are accessible and in addition with the graphical touch screens. Most modernized PLCs can communicate over a system to some other framework, for example, a computer running a SCADA (Supervisory Control and Data Acquisition) framework or web program. PLCs usually have built in correspondences ports generally 9- Pin RS232, and alternatively for RS485 and Ethernet. Modbus or DF1 is normally included as one of the communications protocols. Others' alternatives incorporate different fieldbuses, for example, Device Net or Profibus. Different communication protocols that may be utilized are recorded as a part of the List of automation protocols.

3.3 Line wise control philosophy for the system

The line wise philosophy of the system can be explained from the fig 3, fig.4 and fig.5.

Inspection Conveyor: The inspection conveyor with tag IC001 is a line wise start access and is manually ON/Off on the screen as per the fruit requirement; all the products are with the interlock EL001. If the inspection conveyor is start/stop then all the other supporting equipment will automatically start. If IC001 start showing green color in SCADA, the conveyor is started and waiting for few seconds for all department to provide the necessary feedback. The discharge pump is sending the necessary feedback.

Sorting assembly: When the inspection conveyor has a fruit for the process the fruit is passed to the sorting assembly where the fruit is sorted on the parameters like color, size and maturity of the fruit. After the sorting process the fruit is passed on to the elevator section. The discharge pump is set on then the elevators conveyor is ready to start.

Elevator: Until and unless the discharge pump gives any feedback to the elevator the elevator is not running. The speed of the elevator is adjusted according to the requirement by setting the speed shown on the screen. When the elevator discharge pump is set on then the forward conveyor is set ON.

Forward conveyor: When the discharge pump of the elevator is On the forward conveyor is set in motion. After the sorting technique is done the fruit is transferred in the destoner and only banana is processed in the peeling section. For the other fruits except banana the MP001 mash pump is

present to mash the fruits. If the hopper level is full the conveyor should be stopped. Optional start/stop button for banana production.

Peel fruit conveyor: It works only for the banana production. When the mash pump is ready the peel fruit conveyor is started.

Destoner pump: It is started line wise from the screen. But when the destoner hopper is full then all the backside equipment should be stopped and set on screen with password protection.

Preheater: When the destoning and peeling discharge pump is set to 1 then the preheater is turned on or else the preheater is off. Temperature controls the pulping process. To control the temperature of the pulping process the close loop controller is required. In the close loop system P&ID system is required.

Balance tank: When the discharge pump of the preheater is set to 1 the balance start to work. When both the tank are filled 100%, all the backside equipment are stopped except the preheaters, destonar.

3.4 Sorting system development

We are developing a sorting system prototype which will be sorting the fruit depending on the color and size of the fruit. The components (hardware and software) explanation about each part, algorithms and the method required for the sorting system is discussed in the next part.
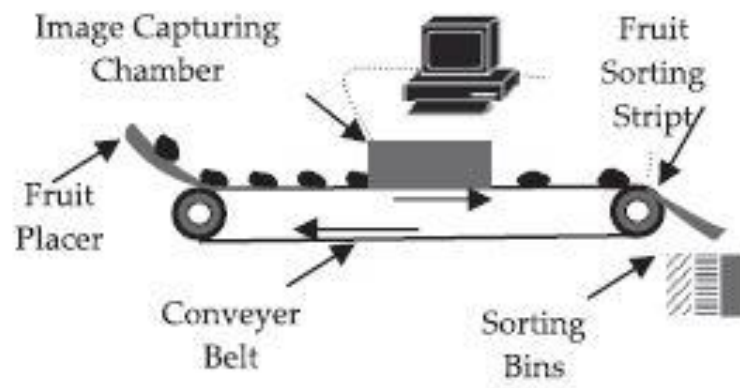

Figure 11 The sorting system prototype [39]

3.4.1 Hardware for the system development solution implementation

➢ 230V, 50Hz
➢ ARM7 Processor V=3.3 V
➢ Web Camera
➢ IR Sensor
➢ DC Motor (L293D) 12V, 10/30 rpm
➢ Load Cell

- ➤ Max.: 15V.
- ➤ Input: 5 V DC input voltage
- ➤ Processor: ARM7TDMI
- ➤ Serial Communication: Max 232 IC
- ➤ Programming in Embedded C
- ➤ Display:20 x 4 LCD

3.4.2 Software for the system development solution implementation

- o Software for PIC
  - Keilµ Vision Version 3
  - Embedded C compiler

- o Software for Image Processing
  - MATLAB Version R2010a
- o Required Outputs
  - LCD display to display current activity.
  - Computer to maintain record and the database.

Hardware overview

The Figure 12 represents the main hardware required to develop the prototype of sorting system. The web camera is the important component in the sorting system because the sorting of fruit is performed by the image capture from the web camera and then it is processed and by using Matlab the image processing is done and the suitable results are obtained and the fruit is sorted accordingly on the parameters of size, color and weight.
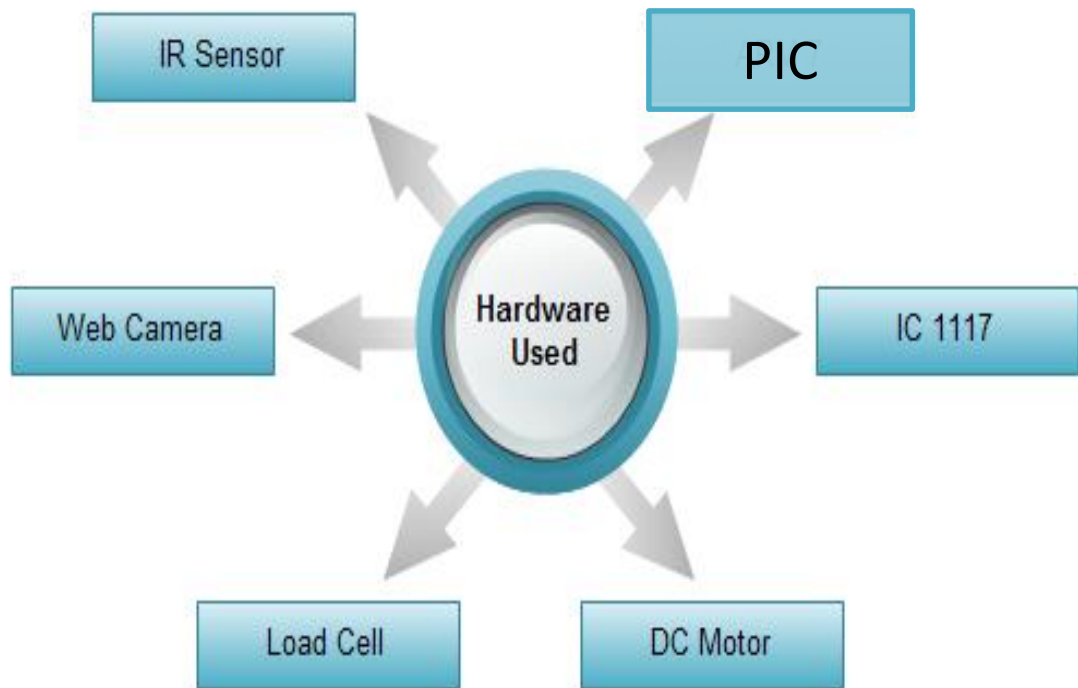
Figure 12 Hardware used for developing a sorting system

The hardware used for developing the sorting assembly is as follows;

- ➢ Pic controller,
- ➢ Regulator IC 1117,
- ➢ Selection of conveyor belt,
- ➢ Dc motor,
- ➢ Web camera,
- ➢ IR sensor,
- ➢ LCD display.

- **Block diagram for developing a sorting system**

Initially all the devices are initialized. When we switch on the system, conveyor belt starts moving. The fruit which is kept on the conveyor belt will be carried along with it. IR sensor which is mounted on the conveyor assembly board will sense the presence of fruit. As soon as fruit comes in front of IR sensor, PIC processor stops the conveyor.

Here the image of fruit will be captured by web camera which is further sent to computer for Image Processing. MATLAB software will process the image of fruit for the parameters such as color, size (edge detection) etc.

The result of Image Processing is sent to PIC controller with the help of serial port (UART). As soon as PIC receives the signal (i.e. result) from MATLAB it will start the conveyor.
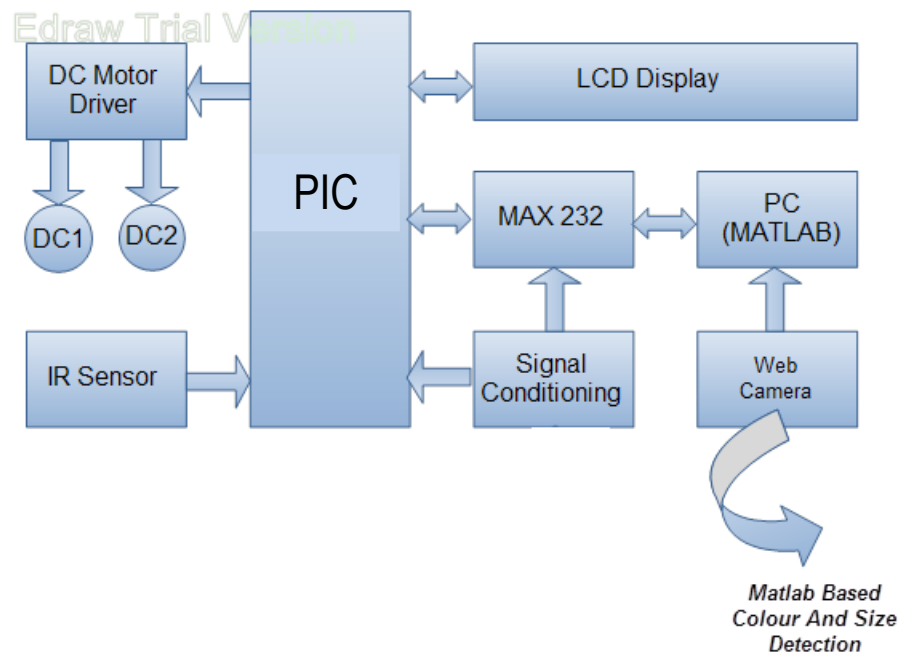
Figure 13 Block diagram for implementing a sorting system

Finally the fruit reaches the Load Cell Assembly for weight measurement. Depending upon the above parameters the Quality of Fruit will be decided and grading is carried out.

We are using PIC 16F877 controller, regulator IC 1117, L293D DC motor driver IC, LCD display,IR sensor,MAX 232 (DS 14C232).

PIC Controller

The PIC controller is useful for connecting the conveyor assembly with the image processing results. When the matlab gives the output by calculating the edges, this output is sent to the PIC controller with the help of serial port (UART). As soon as PIC receives the signal (i.e. result) from MATLAB it will start the conveyor.

Features of PIC 16F877

➢ CMOS 8-bit Flash microcontrollers
➢ Pin compatible with PIC 16C73B/74B/76/77
➢ 3 Timers
➢ 10 bit ADC
➢ PWM output
➢ Synchronous serial port (SSP) SPI and I2C
➢ Serial ports (USART, MSSP)

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- ➢ Parallel Slave Port
- ➢ Capture/Compare/PWM modules
- ➢ Data EEPROM

Applications

- ➢ Industrial control
- ➢ Medical systems
- ➢ Access control
- ➢ Point-of-sale
- ➢ Communication gateway
- ➢ Embedded soft modem
- ➢ General purpose application

Regulator IC 1117

This is type of regulator IC. It converts voltage from 5v to 3.3v which is used to drive PIC controller.

Features

- ➢ The IFX 1117 is a monolithic integrated fixed NPN type voltage regulator that can supply loads up to 1.0 A.
- ➢ The device is housed in the small surface mounted SOT223 package.
- ➢ The IC is equipped with additional protection against overload, short circuit and over temperature.
- ➢ The IFX 1117 GSV33 supplies a regulated output voltage of 3.3 V ($\pm 2\%$).
- ➢ The IFX 1117 GSV supplies an output voltage with $\pm 2\%$ precision adjustable via an external Voltage divider.
- ➢ The input voltage for the IFX 1117 GSV33 ranges from 4.5 V (= V_Q+V_{DR})to 15 V for a load current of 800 mA, for the maximum load current of 1.0 Aa minimum Input voltage of 4.7 V is required.
- ➢ The drop voltage V_{DR} ranges from 1.1 V to 1.4 V Depending on the load current level.
- ➢ The device operates in the temperature range of T_j = 0 to 125 °C.

Conveyor

Conveyor is mechanical gear that is utilized to pass on the materials, bundles, or things being assembled starting with one place then onto the next. There are variety of conveyors, for example, roller conveyors, skate conveyors, belt conveyors and conveyors driven by chains and link. In this anticipate, the belt conveyors sort is utilized to pass on the work-piece. Belt conveyors comprise of a continuous loop, which is the top (half) of the belt, is utilized to convey the materials and the base (another half) of the belt is the return run. It is made of strengthened elastomer (rubber), in this manner it has high adaptability yet low extensibility. Toward the end of the transport is a drive roll that drives the belt. In this prototype, DC motor is utilized as an actuator for the conveyor.
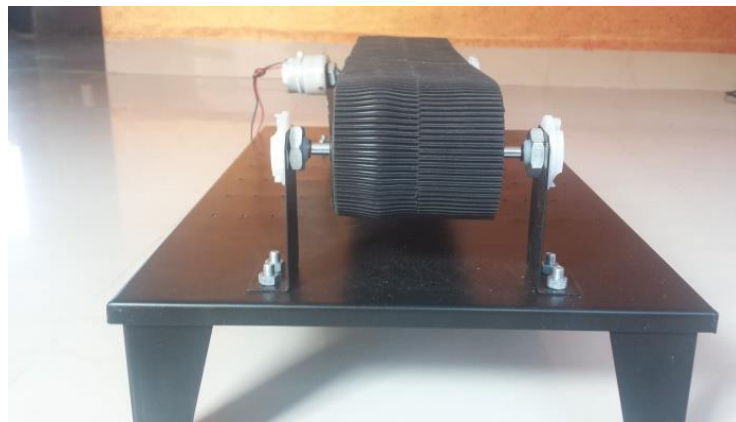

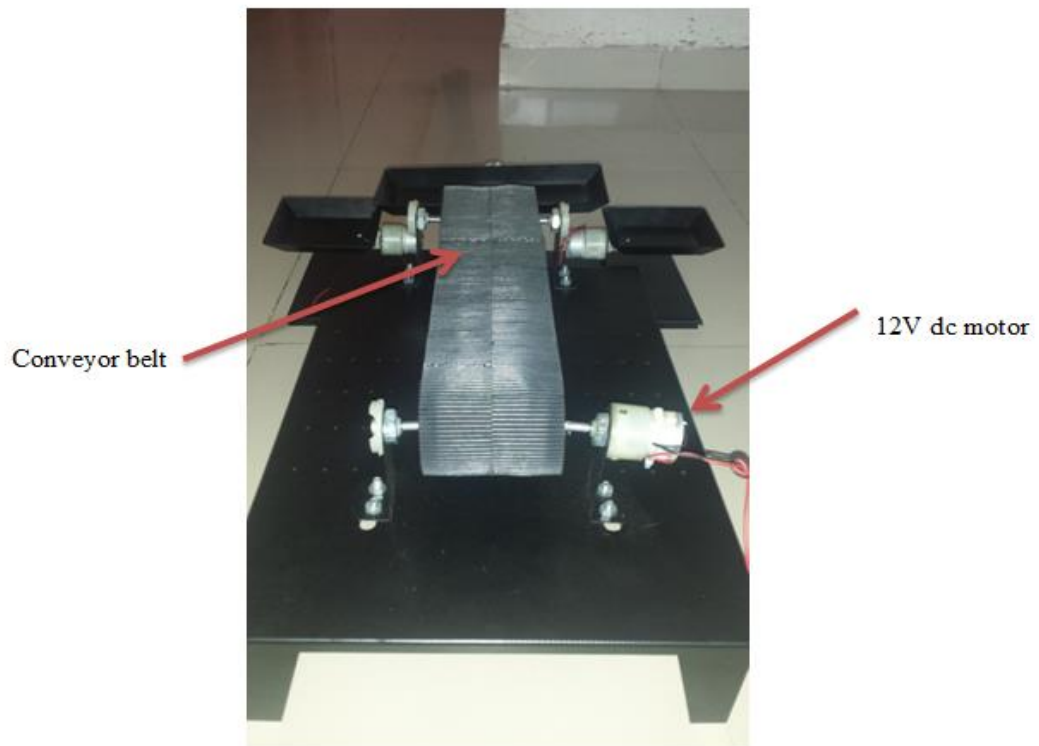**Figure 14 Conveyor belt mounted on the assembly**

Figure 15 Conveyor belt along with DC motor

Calculation for design of belt conveyor

Primary resistance (force) is the force between the object (fruit) and the belt. It can be calculated by the following formula:

$$F_H = L * f * g * (\frac{m_R}{L} + (2 * m'_G + m'_L) * \cos \alpha)$$

F_H = Primary force;

L= length of the conveyor in m;

f= fictive friction factor;

g= 9.81m/s^2;

m_R = total weight of the roller in kg;

m'_L = maximum load moved in kg/m;

m'_G = belt weight in kg/m;

$\cos \alpha$ = mean slope of conveying distance in degrees.

For the prototype of sorting assembly the parameters and the correcting values are as follows:

L = 1; f = 0.02; g = 9.81; m_R =1; m'_L = 0.5; m'_G = 0.3; cos = 15

$$F_H = L * f * g * (\frac{m_R}{L} + (2 * m'_G + m'_L) * \cos \alpha)$$

$F_H = 1 * 0.02 * 9.81 * (\frac{1}{1} + (2 * 0.3 + 0.5) \cos 15))$

   = 1 * 0.02 * 9.81 * (2.06)

   = 0.404 N

The force between the fruit and the belt is calculated as 0.4N.

Secondary resistance (force) is the force between the conveyed material and belt at the feeding location.

The total of the secondary force F_N is taken into account by the correction value C:

$$C = 1 + \frac{F_N}{F_H}$$

The value of C is taken from the catalog given below:

Table 3 Secondary force correction value C depends on the conveying distance L

L[m]	< 20	20	40	60	80	100	150	200	300
C	3	2.5	2.28	2.1	1.92	1.78	1.58	1.45	1.31
L[m]	400	500	600	700	800	900	1000	2000	>2000
C	1.25	1.2	1.17	1.12	1.1	1.09	1.06	1.06	1.05

From the table as the length of the belt is less than 20m the correction value C is taken as 3,

$$3 = 1 + \frac{F_N}{F_H}$$

$$3 = 1 + \frac{F_N}{0.4}$$

$$F_N = 0.8\text{N}$$

The force between the conveyed material and the belt is calculated as 0.8N.

The slope resistance of the conveyed load results from the formula:

$$F_{St} = L * g * m_L' * \sin\alpha$$

L= length of the conveyor [m];

$g = 9.81$ m/s^2;

m_L' = maximum load moved [kg/m];

α = average slope of conveying distance in degrees.

The parameters and the values are as follows;

L = 1; g = 9.81; m_L' = 0.5; α = 15

$$F_{St} = L * g * m_L' * \sin\alpha$$

$$F_{St} = 1 * 9.81 * 0.5 * \sin 15$$

$$= 1.26\text{N}$$

By calculating all the above parameters of the conveyor belt the selection of 12 V dc motor was sufficient to drive the conveyor belt and the selection surface of belt pattern was taken in to consideration the slope resistance of the conveyor belt. The saw tooth belt pattern was selected as the fruit should not slide out from the belt when the motor starts and the conveyor belt moves as the fruit should be on the belt so that the camera captures the photo of the fruit and the processing on the image is taken in to consideration and suitable algorithm are carried in matlab to get to the desired results. Some examples of the type of surface for the conveyor belt are as follows:
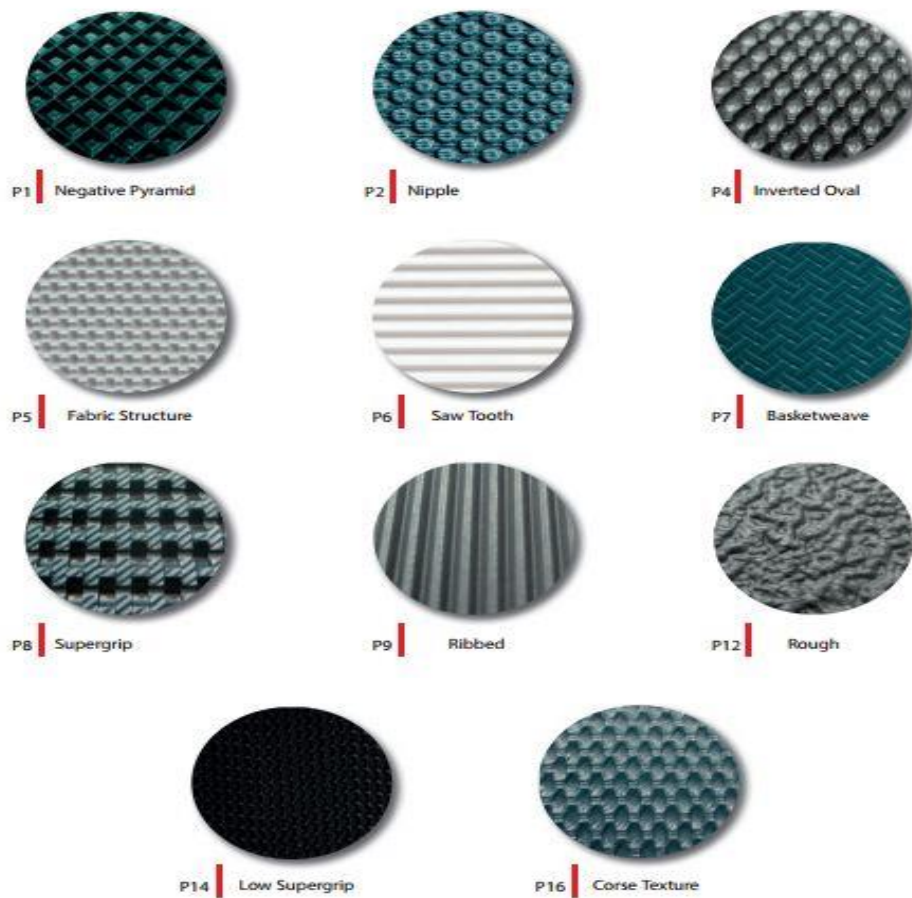
Surface patterns for conveyor belts

Figure 16 Surface patterns

DC motor

- ➢ An Electric Motor is a machine which converts electrical energy into mechanical energy.
- ➢ We have used two DC motors   1)To drive conveyor belt(12v,30rpm)

                      2) To rotate robotic arm (12v, 10rpm)

30 RPM Side Shaft 37mm Diameter Compact DC Gear Motor is appropriate for little robots/computerization frameworks. It has tough development with gear box worked to handle slow down torque created by the engine. Drive shaft is supported from both sides with metal bushes. Motor runs easily from 4V to 12V and gives 30 RPM at 12V. Motor has 6mm measurement, 22mm length drive shaft with D shape for fantastic coupling [38].

Specifications

- ➢ RPM: 30 at 12V
- ➢ Voltage: 4V to 12V

Figure 17 DC motor [38]

- Stall torque: 28 Kg-cm at stall current of 1.3 Amp.
- Shaft diameter: 6mm
- Shaft length: 22mm
- Gear assembly: Spur
- Brush type: Carbon
- Motor weight: 143gms

L293D DC Motor Driver IC

The Device is a monolithic integrated high voltage, high current four channel driver designed to accept standard DTL or TTL logic levels and drive inductive loads (such as relays solenoids, DC and stepping motors) and switching power transistors.

Features Of L293D

- 600mA output current capability per channel
- 1.2 peak output current (non repetitive) per channel
- Enable Facility
- Over Temperature Protection
- Logical "0" input voltage up to 1.5V(High Noise Immunity)
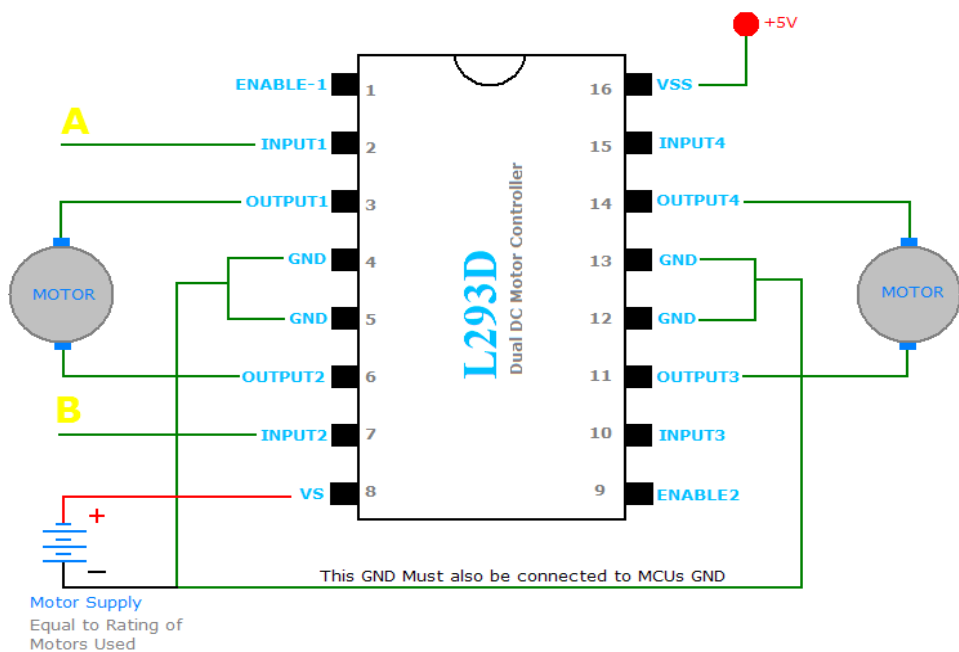- Internal clamp diodes

Figure 18 Electrical connection for driving the conveyor belt

Web camera

Machine vision system used for color imaging of the citrus fruits

Generally, basic image processing system involves computer with video graphics array (VGA), frame grabber, color monitor, illumination system, and CCD camera and image analysis software. The experimental setup consisted of CCD camera that captured images. It is further connected to computer through supplementary hardware then the frame grabber converts the image received in digital form from analog one. To estimate color of the image, image processing algorithms are used to analyze previously obtained digital image.

- **Camera**

In this system PULNIX 6700 progressive scan camera can be used. It has 2/3" CCD element with resolution of 640 × 480 pixels and capture rate of 60 frames per min. Other characteristics that are included in this camera are – remote control through RS232C interface, adjustable shutter speeds etc. The image present in the frame buffer is addressed by the CPU at pixel level through software. In this application, NI1428 frame grabber was used. Care was taken while designing diffused illumination system for capturing clear images that reduced pre-processing and enhanced the image before final analysis is carried out.

IR sensor

- ➢ The sensor includes a LED for outputting infrared rays to sequentially sense an obstacle, and a light-receiving transistor which receives the rays reflected from the obstacle, transmitted by the LED.

- ➢ The IR sensor has a very narrow operating range because of characteristic of infrared Rays.
- ➢ We are using IR sensor for detecting the object on the conveyor belt.
- ➢ When the object is detected the IR sensor transmits the signal to the PIC controller and the controller stops the conveyor belt after 10sec.
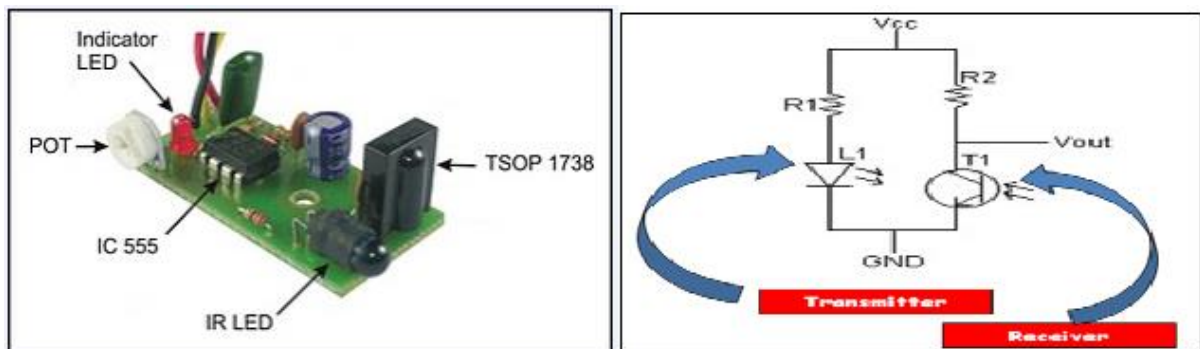

Figure 19 Working principle of IR sensor

LCD display

LCD display is just to notify us with the status of the process and the result which is calculated in matlab and send it to the PIC controller for the further process. In our system we prefer to choose a LCD instead of LED or 7-Seg display to display current activity of project because of the following reasons.

1) It has the ability to display numbers, characters and graphics whereas LED displays are limited to numbers and a few characters.
2) There is refreshing controller in the LCD which reduces the overhead of the CPU.
3) Ease of programming for characters and graphics.

We have used the 16 by 2 LCD that means that it can display the two lines containing 16 characters each. The Pixel Matrix is of 7 by 5 pixels that are each character can be displayed using 7 columns of the pixels and 5 rows of the pixels.
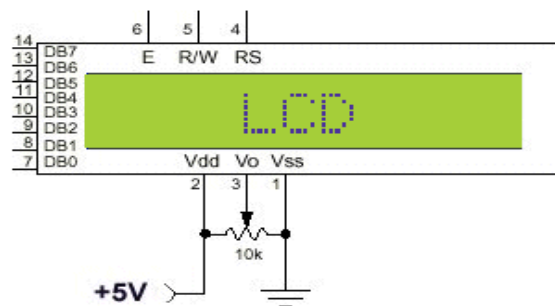

Figure 20 LCD display

To control the operation of the LCD three control signals are used they are as follows:-

1) Enable (EN): It is utilized to display the presentation to perform any operation with it.
 2) R/W (Read/Write): This sign shows to LCD processor that the operation being performed is perused read or write operation.. The indication of 1 means it is read operation and indication of 0 means write operation.
3) RS (Register Select): Registers are of two types one is a command register and the other is a data register. RS signal is used to select one of these registers.

If it is 0 the command register will be get selected and when it is 1 the data register will be selected. There are 8 lines for the data transfer between micro controller and LCD.

Software overview
- **Required Software**
  - ➢ Programming Language -Embedded C
  - ➢ Compiler -Keil uVision3
  - ➢ Computer side Programming

    MATLAB Version R2010a

The parameters of citrus fruits required for sorting were estimated in the proposed image processing technique. It is based on single hue fruit images. Analysis of images was carried out using Matlab (Version R2010a) Image Processing toolbox which extracted color using different techniques.

In the present condition quality of fruit is decided manually, it has various barriers such as undesired way of handling the fruits, lack of sight; parameters for quality may vary from person to person. In short we can't get the good quality fruit. But if we modernize the present system in an automated way then the sorting of fruits which is done manually nowadays will be done in an automated way by using machine vision technology and the sorting of fruits will be carried out on the basis of its color, size, shape which will reduce the undesired handling of fruits. Automatic sorting will overcome the problem of lack of sight and checking the quality of fruit from person to person.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building
- **Read and Display an Image**

Clear the MATLAB workspace of any variables and close open figure windows.

clear, close all

Getsnapshot

Immediately return a single image frame

Syntax:

frame = getsnapshot(obj)

Description

frame = getsnapshot(obj)

Immediately returns one single image frame, frame, from the video input object obj. The frame of data returned is independent of the video input object Frames per Trigger property and has no effect on the value of the Frames Available or Frames Acquired property.

- **To read an image**

use the "imread" command.

The example reads one of the sample images included with the Image Processing Toolbox, pout.tif, and stores it in an array named I. I = imread('pout.tif');

imread infers from the file that the graphics file format is Tagged Image File Format (TIFF). For the list of supported graphics file formats, see the imread function reference documentation. Now display the image. The toolbox includes two image display functions: imshow and imview. You can use either one to display an image. imshow(I)

- **Display an image**

imshow Display an image

imshow filename displays the image stored in the graphics file filename.

imshow calls imread to read the image from the file, but the image data is not stored in the MATLAB workspace. The file must be in the current directory or on the MATLAB path.

h = imshow(...) returns the handle to the image object created by imshow.

- **Convert an RGB image or color map to grayscale**

rgb2gray

Syntax: I = rgb2gray(RGB)

newmap = rgb2gray(map)

Description

rgb2gray converts RGB images to grayscale by eliminating the hue and saturation information while retaining the luminance.

I = rgb2gray(RGB) converts the true-color image RGB to the grayscale intensity image I.

newmap = rgb2gray(map) returns a grayscale color map equivalent to map.

4. Developing a prototype of sorting system

4.1 Setup for the sorting system

In this section, we describe the fruit grading and sorting system that is built in my previous studies, in my bachelor engineering. The system has a motor driven conveyer belt and a fruit placer. The fruit placer places one fruit at a time on the belt and the belt carries it to the imaging chamber where the fruit image is captured and transferred to the connected image processing and classification system (in this case a computer that is connected to the imaging chamber). The classification result is send to a sorting unit that directs the fruit to an appropriate bin by moving a strip which is controlled by a motor. The detailed design used for developing the system is described below:
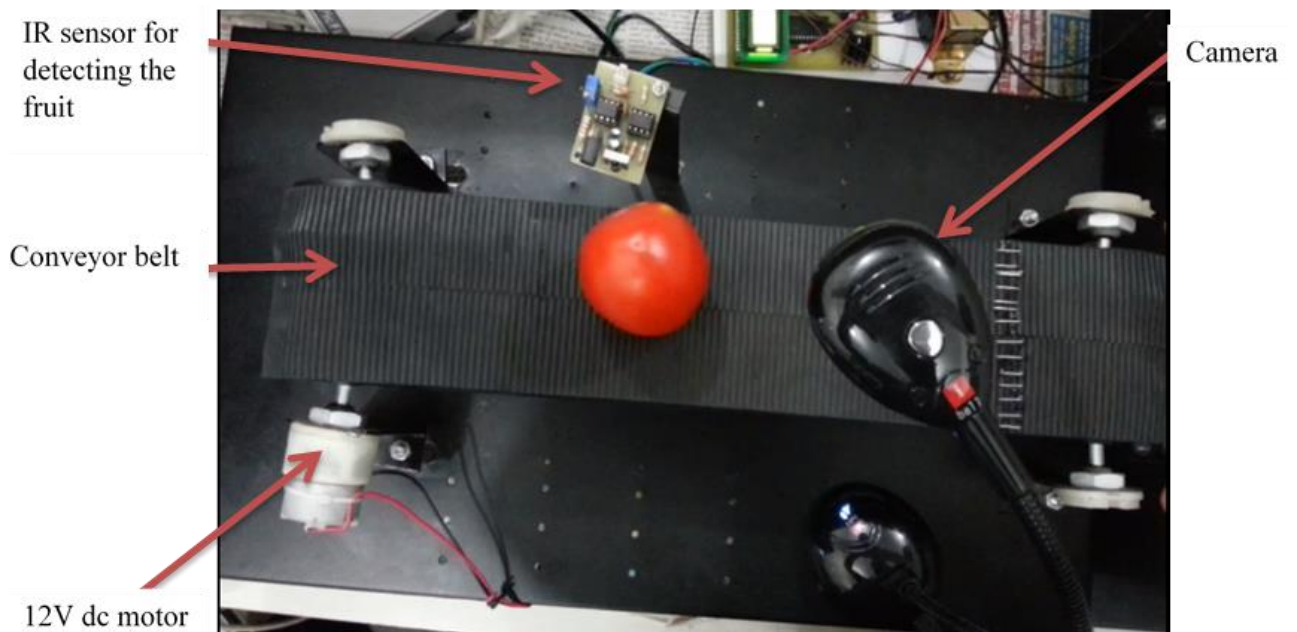

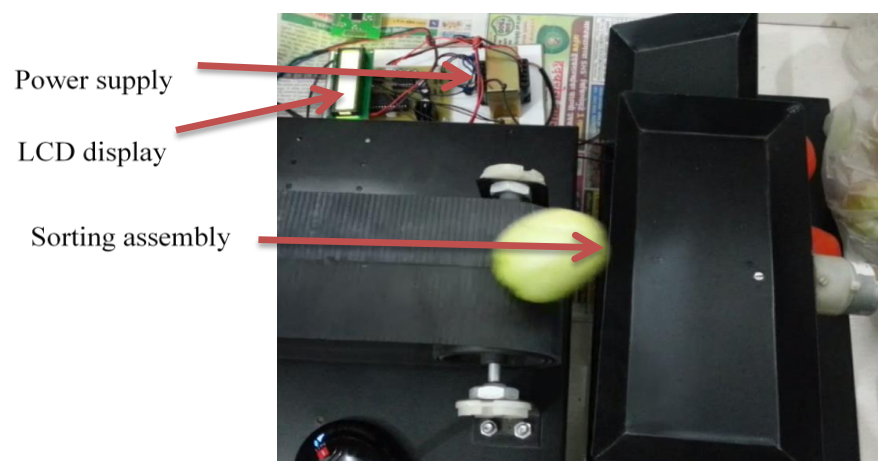**Figure 21 a) Prototype of implemented fruit sorting system**

Figure 22 b) Sorting assembly

Image capturing chamber

The image capturing chamber is a wooden box that was painted black inside to reduce the light reflection. The ceiling of the chamber was quoted with reflective material to reduce the shading effect. In this system PULNIX 6700 progressive scan camera was used. It has 2/3" CCD element with resolution of 640 × 480 pixels and capture rate of 60 frames per min. Other characteristics that are included in this camera are - remote control through RS232C interface, adjustable shutter speeds etc. The image present in the frame buffer is addressed by the CPU at pixel level through software. In this application, NI1428 frame grabber was used. Care was taken while designing diffused illumination system for capturing clear images that reduced pre-processing and enhanced the image before final analysis is carried out. The size of the captured image was 640* 480 pixels. It was kept small for fast feature extraction and processing.
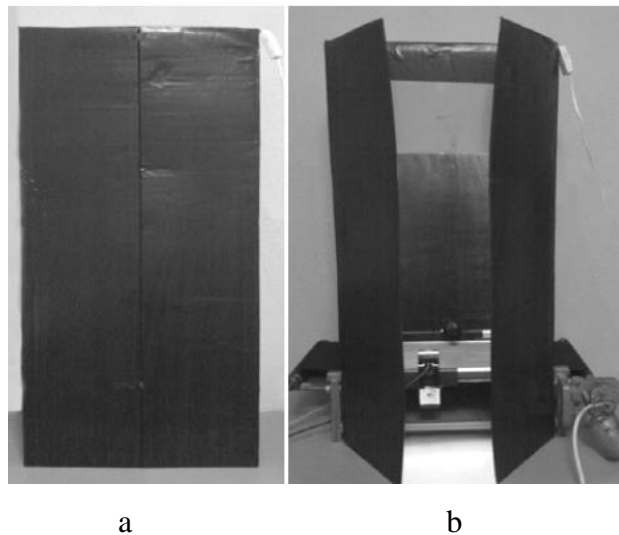

a   b

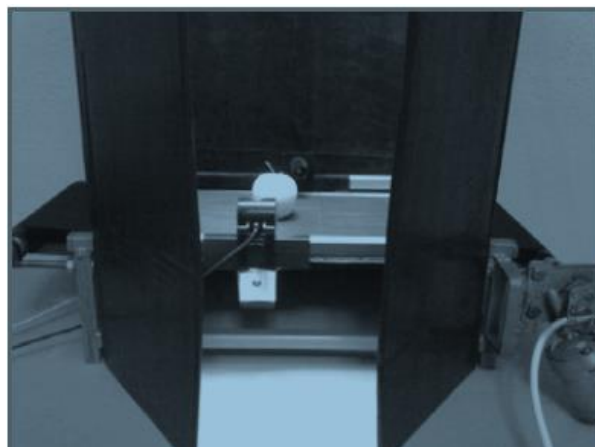**Figure 23 Box used for light insulation a) closed view b) open view**

Figure 24 View of the system during operation

4.2 Method and algorithm for sorting.

Sorting of fruit on the parameter of its size

The fruit size is another quality attribute used by farmers − the bigger size fruit is considered of better quality. The size is estimated by calculating the area covered by the fruit image. To compute the area, first the fruit image is binarized to separate the fruit image from its background. The number of pixels that cover the fruit image is counted and considered as an estimate of size. We categorize fruits as big, medium and small using the average area and variance relationship: A _ kr2; where A is the average of the normalized area and r2 is the variance obtained from the training data set. If the normalized pixel count in a fruit image is A, and A< A _ kr2; where k is has been experimentally estimated to be 1.45, then the fruit is categorized as small. If A _ kr2 < A< A þ kr2 then it is categorized as medium; otherwise it is considered big [39].

Color detection based on maturity of the fruit

The color of fruit's surface determines its maturity. So it can be considered as an important parameter. The algorithm for calculating the maturity of fruit is shown in the figure.9. Initially unripe fruits show greenish surface color which changes to yellow or orange shades of color when matured. The change in color is similar for particular variety of fruits. For e.g. raw alphonso mangoes are green, they turn yellowish orange upon ripening. Even we use color of fruits to judge its ripeness [21]. The captured image of fruit used RGB color space to measure the color discrepancy. The percentage of red component was measured as $R/(R + G + B) \times 100$, where R, G, and B resembles the red, green, and blue components, respectively, likewise the percentage of blue and green components were also measured [21]. The R/G ratio (red component to the green component) was used as a parameter to sort fruits based on their maturity. The maturity sorting was carried out using hue mean and median values of hue. The ranges and the classifying categories were based on requirements of consumers and graders in food processing industry.

Edge Detection

The identification of edge focuses is generally spread among article acknowledgment conspires, and that is the motivation behind why it is said here, in spite of the fact that it is not an item acknowledgment technique in itself. A definite depiction could fill a complete book; subsequently just a short blueprint of some fundamental standards should be given here. Edge focuses are described by high nearby force changes, which are run of the mill of pixels situated on the fringe of items, as the foundation shading regularly contrasts fundamentally from article

36

shading. Notwithstanding that, edge focuses can likewise be situated inside the item, e.g., because of composition or as a result of a quick change of the article surface typical vector, which results in changes of the force of light reflected into the camera.

Scientifically, high neighborhood force changes compare to high first subsidiaries (slopes) of the power capacity. In the accompanying, the Sobel Operator as a normal strategy for quick inclination computation is clarified. Moreover, the Canny edge indicator, which notwithstanding angle computation, additionally orders pixels as "edge point" or "non-edge point" might be displayed.
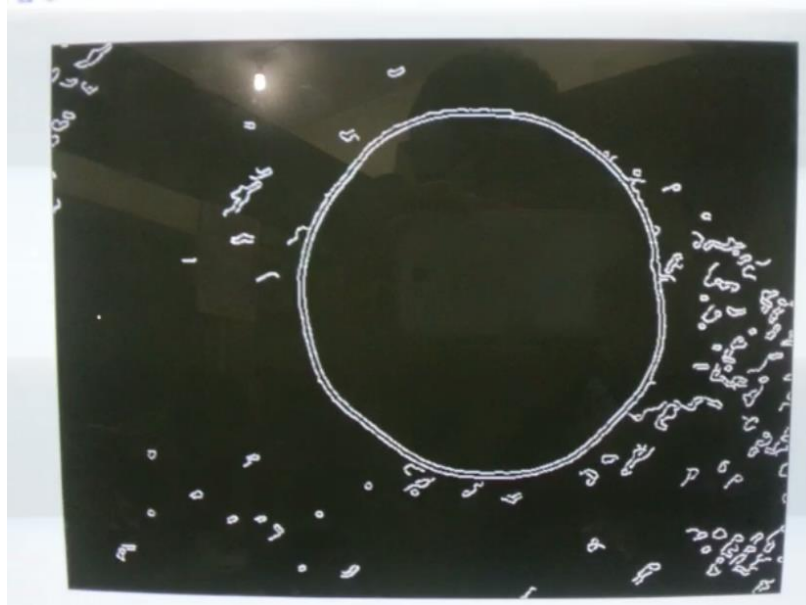

Figure 25 Screen shot of the edges detected of a fruit by applying canny edge detector algorithm

Be that as it may, first how about we specify a couple reasons why edge location is so prevalent:

• Information content: a great part of the data of article area is focused on pixels with high slope. Envision a basic plain splendid item upon a dull foundation: if its position changes somewhat, the power of a pixel situated close to the inside will basically not change after development. In any case, the force of a pixel, which is likewise situated inside the article, yet near its fringe, may change significantly, in light of the fact that it may be situated outside the item after development.

• Invariance to brightening changes: brilliance counterbalances and in addition direct splendor changes lead to varying intensities of each pixel. The primary subsidiary of the force capacity, nonetheless, is less influenced by those progressions: consistent counterbalances, for instance, are counteracted totally.

• Analogy to human vision: to wrap things up there is confirmation that the human vision framework, which obviously has capable acknowledgment abilities, is touchy to ranges highlighting fast power changes, as well.

Canny Edge Detector

A standout amongst the most well-known identifiers of edge pixels was created by Canny [31]. As far as inclination figuring is concerned, Canny planned some alluring properties that a decent inclination administrator ought to satisfy and discovered that convolutions of I with the primary subsidiaries of the Gaussian channel portion in x-and additionally y-heading are great approximations. After slope separating, the yield must be thresholder in a few path so as to choose which pixels can be delegated "edge pixels" [40].

Presently how about we have a more critical take a gander at the optimality criteria characterized by **Canny:**

 ➢ Good location quality: in a perfect world, the administrator ought not miss real edge pixels and additionally not mistakenly arrange non-edge pixels as edge pixels. In a more formal dialect, this relates to an expansion of the sign to-commotion proportion (SNR) of the yield of the inclination administrator.

 ➢ Good restriction quality: the reported edge pixel positions ought to be as close as could reasonably be expected to the genuine edge positions. This necessity can be formalized to a minimization of the difference of the distinguished edge pixel positions.

 ➢ No various reactions: a solitary genuine edge pixel ought to prompt just a solitary reported edge pixel also. All the more formally, the separation between the extricated edge pixel positions ought to be boosted [40].

An example of the different steps of the canny edge detector can be seen in Fig.27 [40];

| a | b | c | d | e |

Figure 26 An example of the Canny operator is shown: a) intensity image; b) output of gradient filter in pseudo color, the gradient magnitude increases in the following order: black – violet – blue –green – red – yellow – white; c) gradient after non-maximum suppression in pseudo color; d) detected edges with high thresholds; e) detected edges with low thresholds [40]

Obviously there are numerous contrasting options to the canny edge channel. Deriche [32], for illustration, created recursive channels for figuring the smoothed inclination which are streamlined concerning speed. Freeman and Adelson [33] proposed to supplant the Gaussian-based channel by purported quadrature sets of steerable channels in Canny's system. They contended that the channel determined by Canny, which is advanced for step-edges, is imperfect on account of different forms, e.g., bar-like structures or intersections of various edges. In this manner they determined a vitality measure structure quadrature sets of steerable channels as an option, which indicates great results for an assortment of edge sorts.

5. Development of the control part of the sorting

- Fruits Used: Any circular fruit like Apple, Tomato, Orange.
- Grading criteria of fruits: 1) Fruits of specific color
                                         2) Fruits of specific size
                                         3) Fruits of specific weight

eg. Tomato

The segmentation for the sorting technique for the tomato is explained in short detail as follows. When the fruit is processed form the conveyor belt and the image of the fruit is captured and the captured image is then processed in image processing and the fruit is sorted on the basis of its color, i.e. red or green. Then the captured image of fruit is again processed for the edge detection of the fruit for sorting it on the parameter of its size. If the fruit is selected as a red fruit then on the red fruit the parameters of the size are calculated by using canny edge detector. Edge detector sorts the fruit by comparing the value with the stored value in the database.
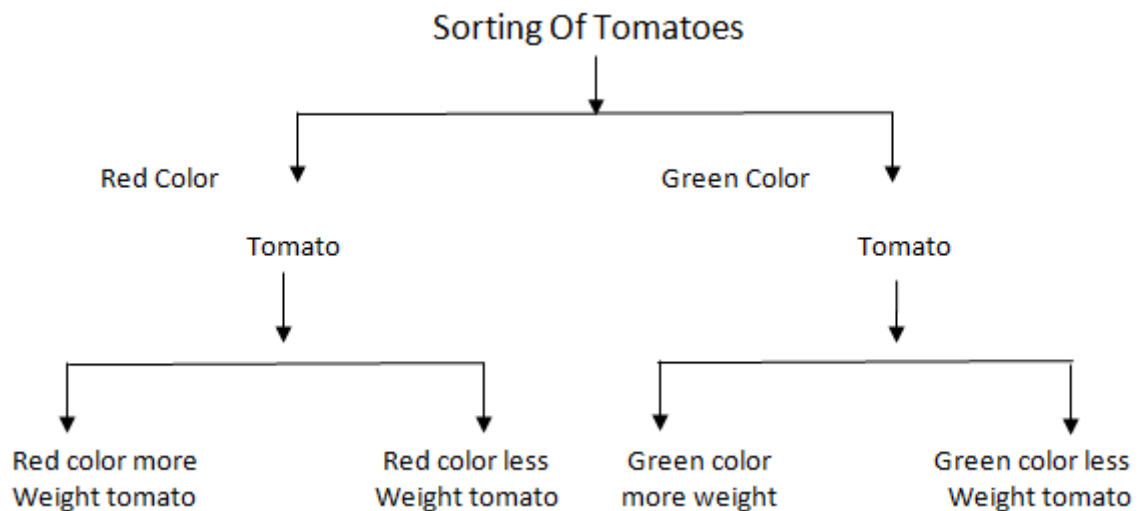

Figure 27 The flow of sorting process

Grading: Grade A Red color tomatoes having more weight (diameter 4cm)
              Grade B Red color tomatoes having less weight (diameter 3cm)
              Grade C Green color tomatoes having more weight (diameter 4cm)
              Grade D Red color tomatoes having less weight (diameter 3cm)

The process for the color sorting of the fruit is carried out in the following manner shown in figure 29. When the fruit is on the conveyor belt and the web camera captures the picture of the fruit after the IR sensors detects the object, the captured image is passed on to the computer and the image processing on that captured image is performed in matlab. The matlab calculates the area of

the image captured, compares it with the database of images and then sends the command to the controller and then the fruit is selected or rejected according to the parameters defined.
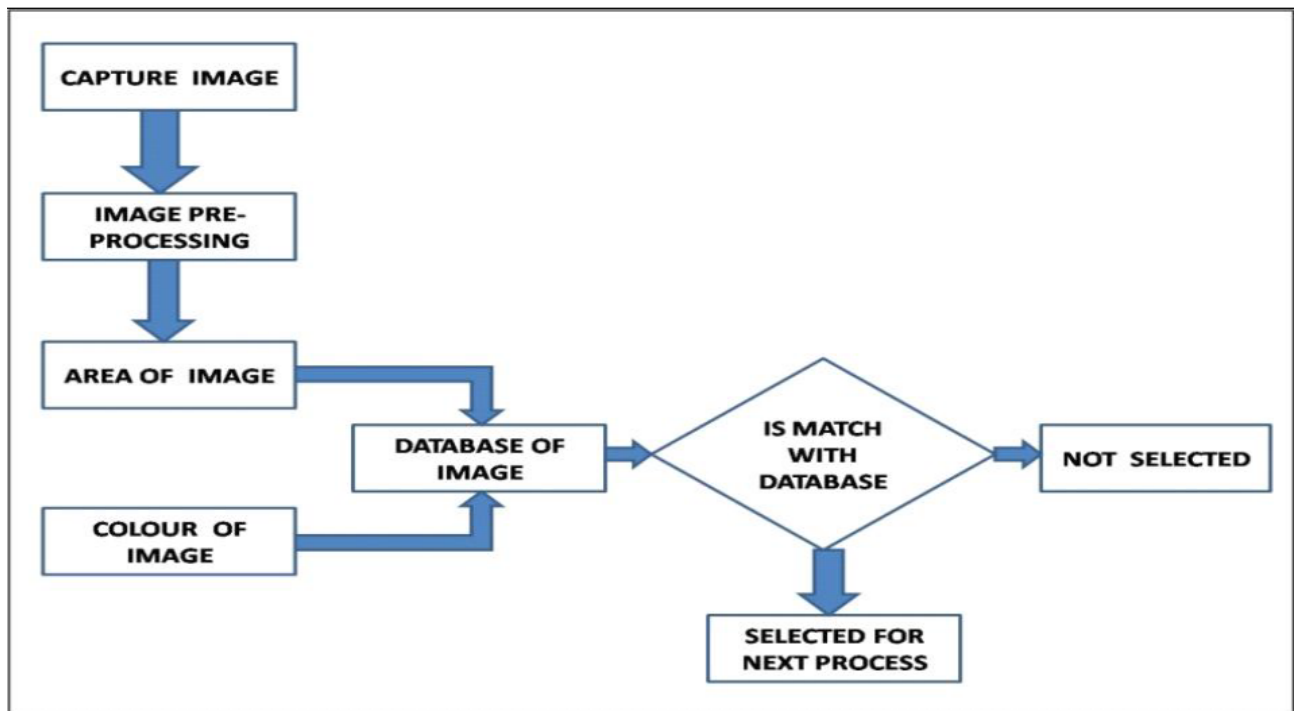
Figure 28 System flow for sorting on basis of color

➢ The system flow figure 30 and 31 resembles the complete process of the mechanism of the developed prototype.

➢ When the system is set to start firstly all the devices are initialized and the status from all connected devices is taken into consideration.

➢ Then the IR sensor is checked for any object detected. If it detects any object then the conveyor belt is stopped accordingly by the stop time pre-defined.

➢ Then the image of the detected object is captured and transmitted to the PC for the feature extraction of the captured image.

➢ In figure 31 the maturity of the fruit is checked according to the color samples.

➢ The captured image is processed and the sum of all the red and green samples is taken into consideration.

➢ By evaluating the ratio of R/G the fruit is considered as ripe, unripe.

➢ When the controller gives command the conveyor is activated and the object is sorted accordingly to the features extracted.
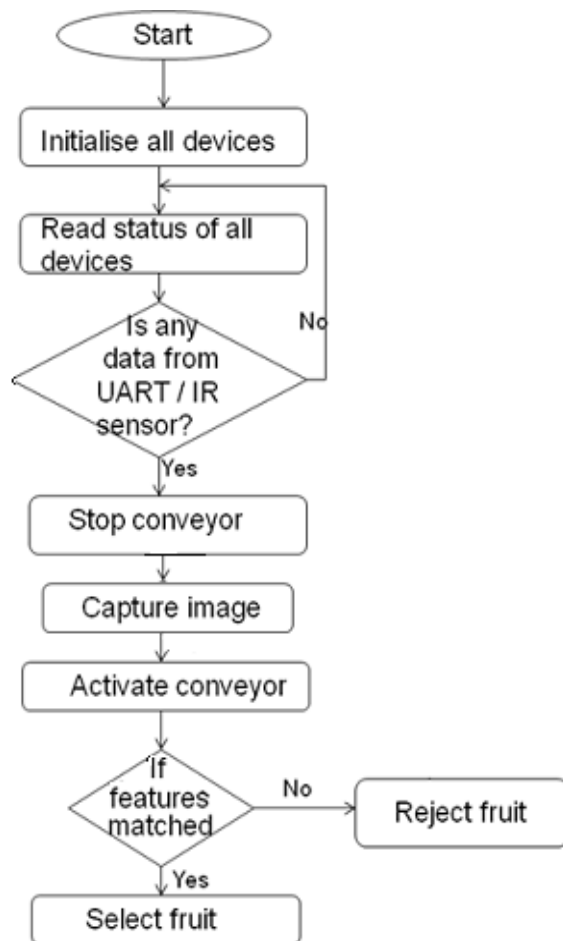
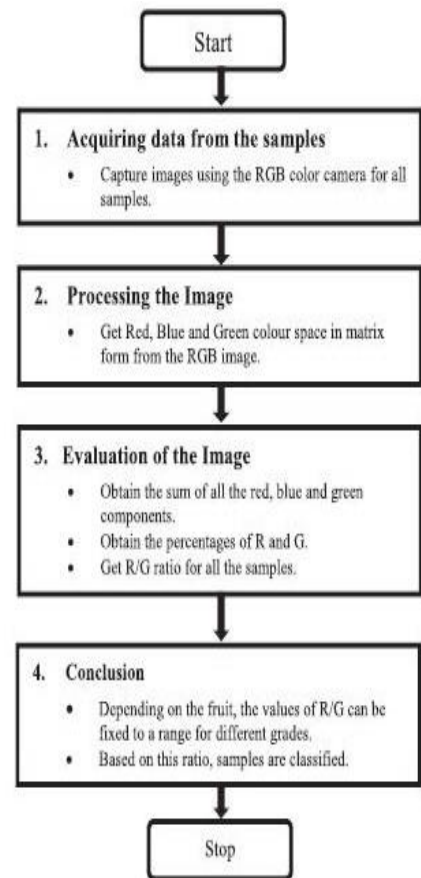**Figure 29 System flow for sorting on basis of size**

Figure 30 Algorithms used in the proposed methods of maturity analysis

6. Results for object recognition depending on the color and size

Here in this result we have an apple with a color detected as red and the canny edge detector detects the edges of the captured image of an apple and it compares with the specified threshold for checking the size of the apple and it is indicated as a small red apple.
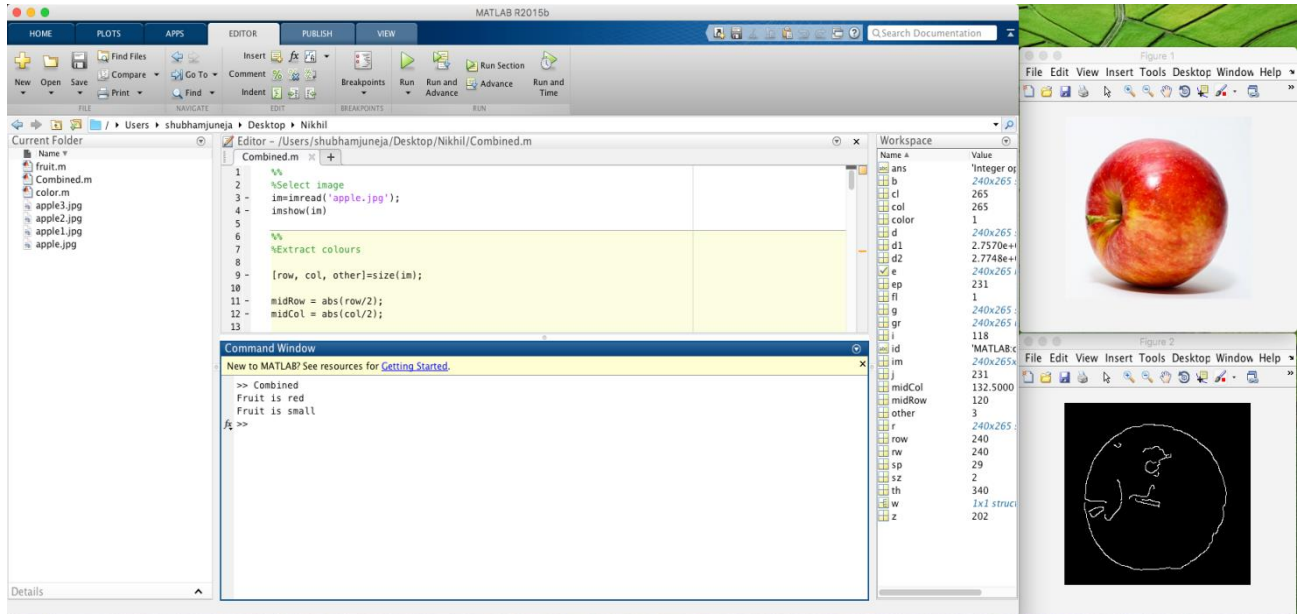

Figure 31 Screenshot of the simulation indicating big red apple along with along with its detected edges

Now we have a big apple with a bigger size. Canny edges are considered and we can see that the number of pixels (diameter) is more than the specified threshold; hence it considers the apple of red big apple.
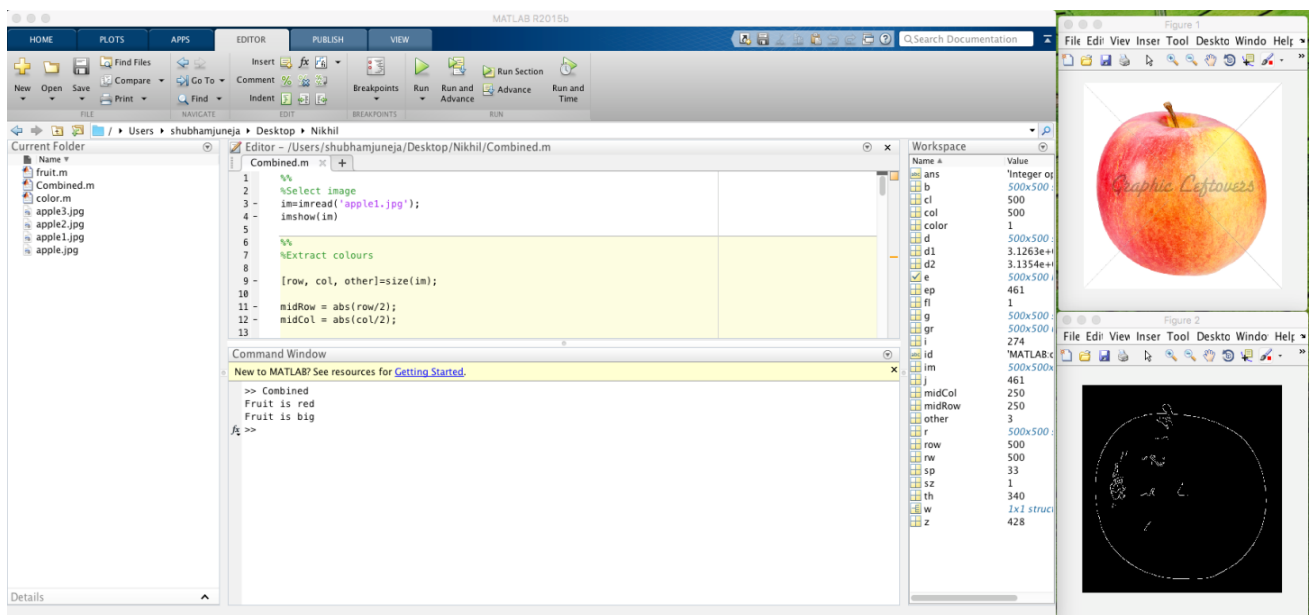

Figure 32 Screenshot of the simulation indicating small red apple along with along with its detected edges

Similarly it is done for the green apples. It identifies the center pixels of the image as having more green color than the red and then the canny edge detector detects the edges and it is compared with threshold and the output is displayed as the apple is green with big in size.
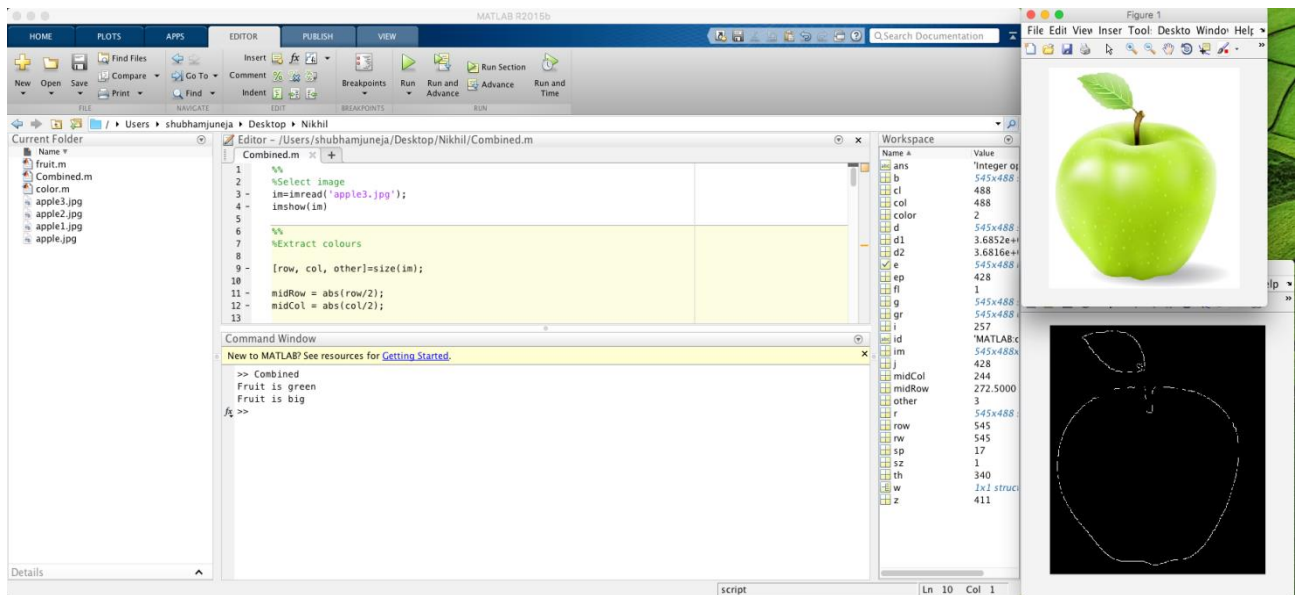

Figure 33 Screenshot of the simulation indicating big green apple along with along with its detected edges
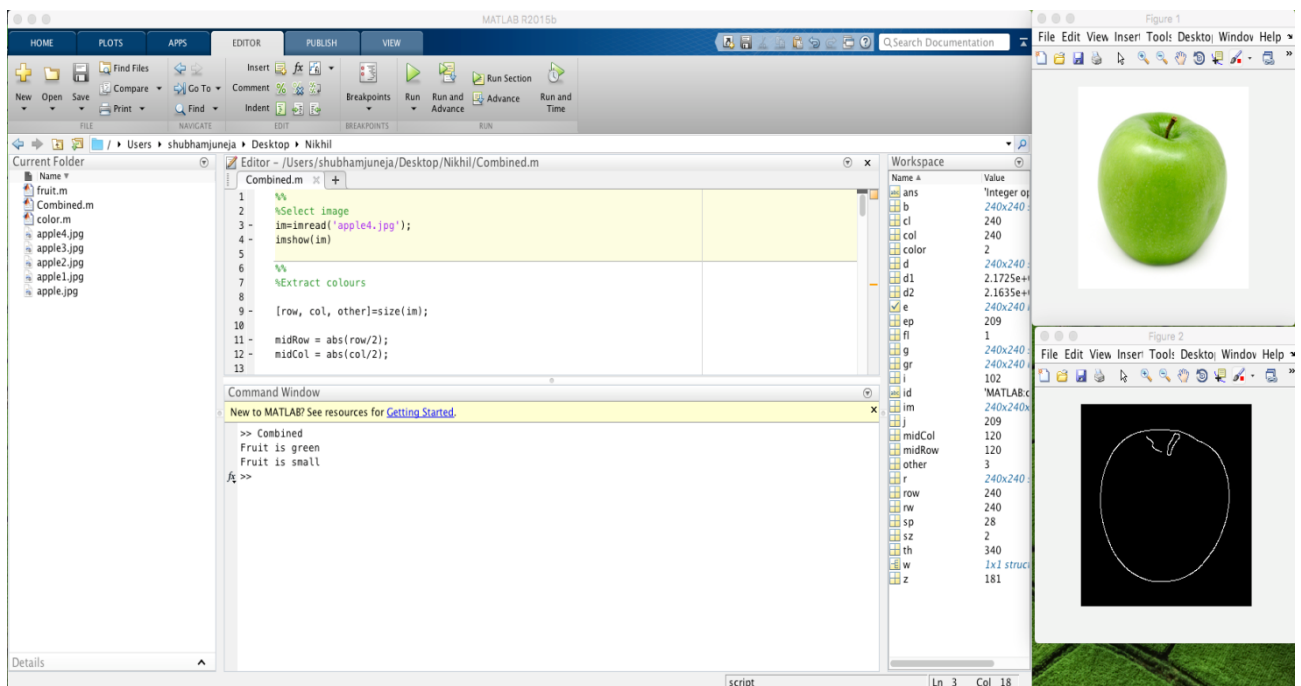
Similarly it is done for green small apple.

Figure 34 Screenshot of the simulation indicating small green apple along with along with its detected edges

From the above calculated results on the developed prototype we can recognize the fruit depending upon the color and size of the fruit by applying the suitable algorithms and detecting the edges of the captured fruit image and we can sort the fruit as per the requirements for the manufacturing process.

Conclusions

- The analysis on the current fruit processing was done and the development on the current state is proposed.

- The manual fruit processing system is successfully developed in to an automatic system by using cross wise selection matrix and by applying the adjacency list and developing the automation by using ladder logic.

- The prototype of object detection in sorting system was analyzed and the techniques evaluated in my previous studies were useful to improvise the current system and the efficiency was increased. The object detection system identifies the color and the size, diameters of apples as the object robustly based on the assumption that the object lies at the center or somewhere close around the center of the camera on the conveyor belt. The results were observed for both the cases i.e. for red big apple, red small apple and green big apple and green small apple. Increasing the conveyor chain velocity led to increase the productivity but it may lead to decrease the prototype efficiency and increased the percentage of damage at all different factors. The grading efficiency increased with increasing the stopping and delay of measurement time. As well as increasing the stopping time leads to decrease the percentage of damage, but also decreased the prototype productivity. The best degrees of grading efficiency obtained by stopping time. This prototype of grading succeeded for purpose as a step forward to the complete design for optimal grading machine.

- The control type of sorting system was successfully developed on a smaller scale and the fruit was recognized and sorted depending on the color and size. According to the research proposed algorithms were evolved for sorting the required citrus fruits like sweet limes, oranges and grapefruits using single view fruit images based on external parameters like color and maturity. Ripeness of fruits is indicated from the color of the fruits. Since color is important factor for determining the ripeness of the fruits, color classification was applied to find ripeness of fruits belonging to same variety. Maturity sorting was done based on R/G ratio. Moreover, the analysis of color has shown that the hue parameter had helped in determining the maturity. This sorting was similar to the human vision inspection. Hence, color analysis of fruits has proved to be important for maturity based sorting as color change in fruits is crucial indicator. The aforementioned algorithm with some modifications can be used for classification of other fruits like mangoes, apples, bananas, etc.

Future development

- ➢ The sorting prototype is developed on a small scale so the results are calculated on the limited images.
- ➢ But when we implement the prototype in the plant we can modify certain parameters of the assembly according to the requirement.
- ➢ At present for capturing the image the conveyor belt is stopped but when we implement it in the real time world we can implement the camera in such a way that the image is captured on the moving conveyor and image processing is done on the captured image.

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Appendix

Designing the power supply for the prototype of sorting system.

The basic step in the designing of any system is to design the power supply required for that system. The steps involved in the designing of the power supply are as follows,

1) Determine the total current that the system sinks from the supply.

2) Determine the voltage rating required for the different components.

Fig.Power Supply
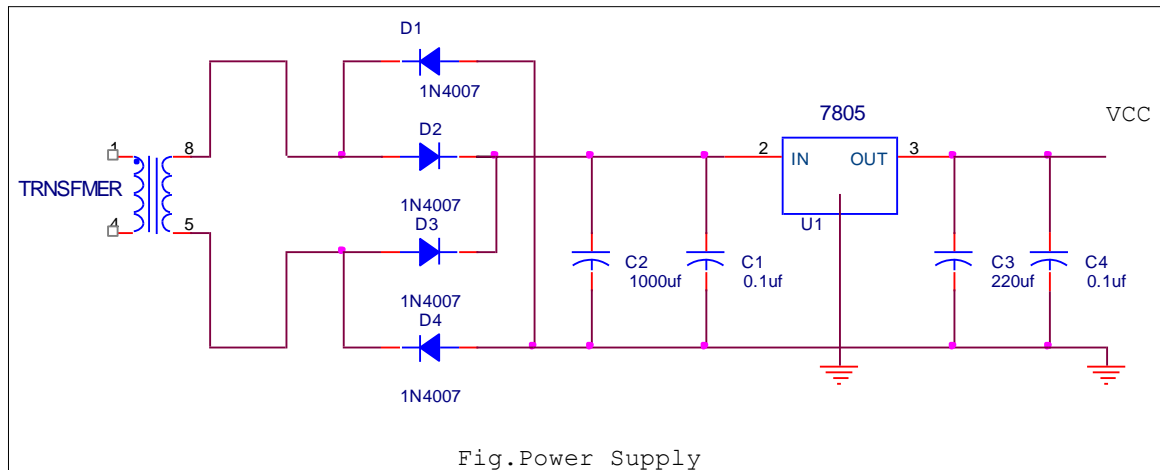
Transformer selection we required 12V for relay.

Min Input for 7805 is

= Drop across IC 7805 + Required Output voltage

= 3 V+ 5V

= 8 V

So at Input of 7805 we required 8 V with margin

Consider drop across diode 0.7V so 2 diode conducts drop is 1.4 V

= 1.4 V +8 V

= 9.4 V

So at secondary we required 10 V

For filter capacitor design

$$C = (I_l * t_1)/V_r$$

V_r = ripple voltage

I_l = load current

T1= time during which the capacitor being discharge by load current

$$\theta_1 = \sin^{-1}[(E_0 \text{ min})/ (E_0 \text{ max})]$$

So unregulated power supply is design for 10 V

V_r = ripple voltage 10% of output voltage

V_r = 1.0 V

$$E_0 \text{ min}/E_0 \text{ max} = (10-0.7) / 10+0.7$$

$$= 9.3 / 10.7$$

$$\theta_1 = \sin^{-1} [9.3/10.7]$$

$$= 60°$$

Frequency 50 HZ

T1 = 1/50 = 20 ms

T for 360° = 20ms

For 180° = 10ms
    For 60° = 20ms * (60°/360)
          = 3.4ms

For bridge

$$T1 = [\text{time for } 90° + \text{time for } \theta1]$$
$$= 5ms + 3.4ms$$
$$= 8.4ms$$

Il = load current supplied to various IC
Il = (O/P current of IC 89c51 +
               O/P current of IC 232 +
               Current req. for display)
       = 71mA + 30mA + 15.2 mA
       =116.2 mA

C = (Il * t1)/Vr
$$= (116.2 \text{ mA} * 8.4 \text{ ms})/ 1 \text{ V}$$
$$= 976.04 \text{ μf}$$
So we select ~ 1000 μf capacitor

For diode design
PIV = Vm
Vm = E0 max + 2 Vf
  = 10.7 + 1.4 V
  = 12.1 V
I0 = Il/2
  = 116.2 mA/ 2
  = 58.1 mA

Peak repetitive current
Ifm = [Il (t1+t2)]/t2
         T2 = time for 90° - time for θ1
           = 5ms - 3.4ms
           =1.2ms
Ifm = 116.2mA (8.6ms+1.2ms) /1.2ms.
              =833mA

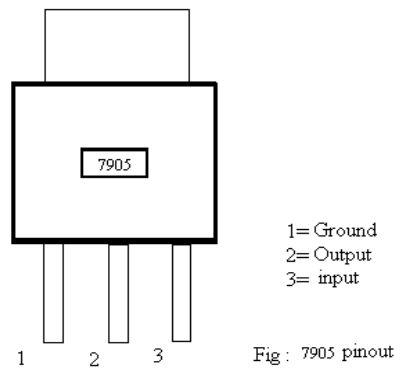From above specification diode 1N4007 is selected
PIV =100V
I = 1A

- **Negative Voltage Regulator 7905:**

The L7900 series of three-terminal negative regulators is available in TO-220, ISOWATT220TO-3 and D2PAK packages and several fixed output voltages, making it useful in wide range of applications.

1= Ground
2= Output
3= input

Fig : 7905 pinout

Voltage regulator

Description

The L7900 series of three-terminal negative regulators is available in TO-220, ISOWATT220TO-3 and D2PAK packages and several fixed output voltages, making it useful in a wide range of applications. These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation; furthermore, having the same voltage option as the L7800 positive standard series, they are particularly suited for split power supplies.

In addition, the -5.2V is also available for ECL system. If adequate heat sinking is provided, they can deliver over 1.5A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

Features

- Output Current up to 1.5 A
- Output Voltages of -5; -5.2; -6; -8; -9;-12; -15; -18; -20; -22; -24V
- Thermal Overload Protection
- Short Circuit Protection
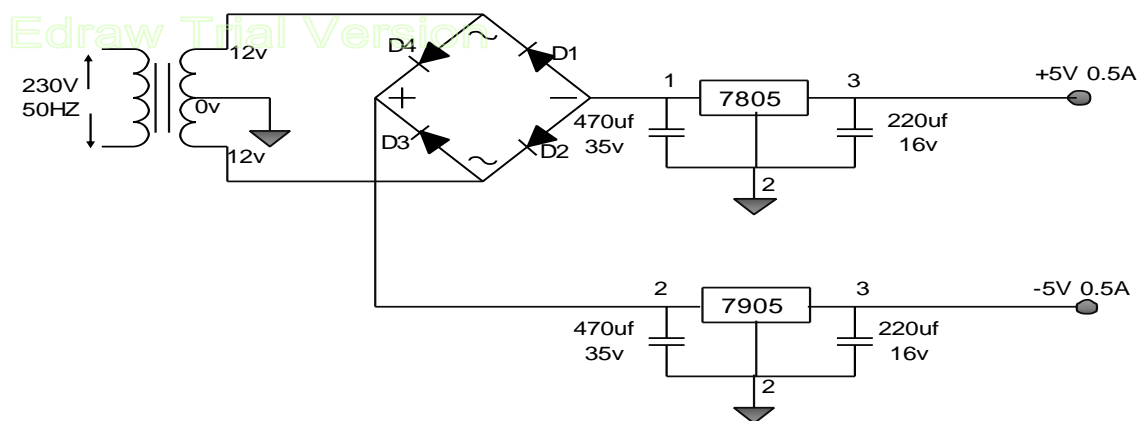
Negative Power Supply

For signal Conditioning of Load Cell   +/- 5V power supply is required.

For this purpose 7905 IC is used .This provides regulated voltage of positive and negative voltage polarities. Fig shows design of regulated power supply for +/- 5V.

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This supply is used as VCC and VEE of operational amplifier.

Reasons for choosing Bridge rectifier are

- The TUF is increased to 0.812 as compared the full wave rectifier.

- The PIV across each diode is the peak voltage across the load =Vm, not 2Vm as in the two diode rectifier

Output of the bridge rectifier is not pure DC and contains some AC some AC ripples in it. To remove these ripples we have used capacitive filter, which smoothens the rippled out put that we apply to 7805 regulators IC that gives 5V DC. We preferred to choose capacitor filters since it is cost effective, readily available and not too bulky.

Circuit Diagram of sorting assembly based on my previous studies.
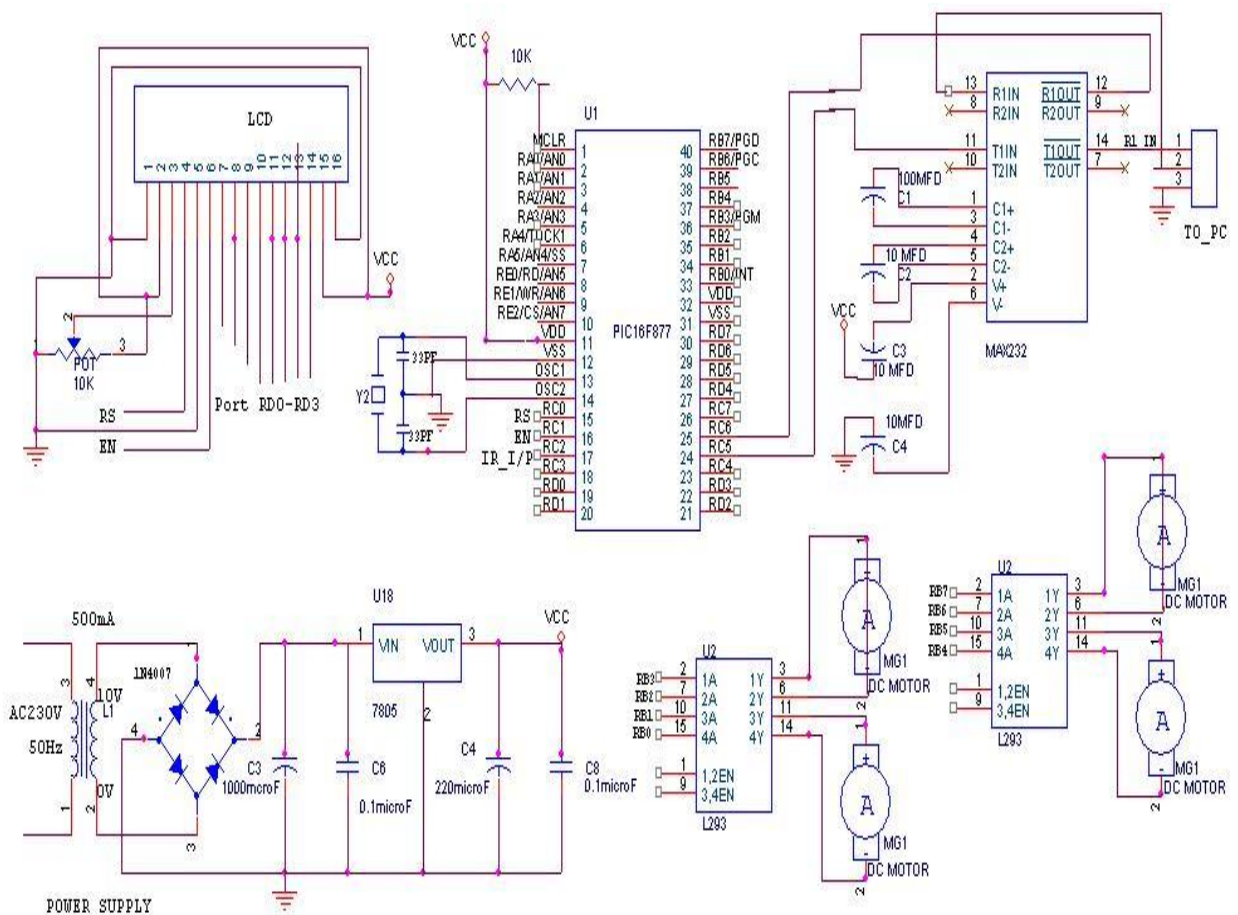
Results and discussions on precious research

Forty- five oranges were used for color distance analysis and for maturity analysis. A few of them (C1 to C15) are shown in Fig. 20. Along with oranges, 45 sampled sweet-limes were used for LDA and PDF analysis and also for maturity analysis. They (M1 to M15) are shown in Fig. 21. In both cases, sample fruits were divided as unripe fruits, moderately ripe fruits, and ripe fruits respectively. Using the MATLAB Image Processing toolbox, the Red (R), Blue (B), and Green (G) color space in matrix form were acquired from RGB images of already captured color images of sampled oranges and sweet-limes.
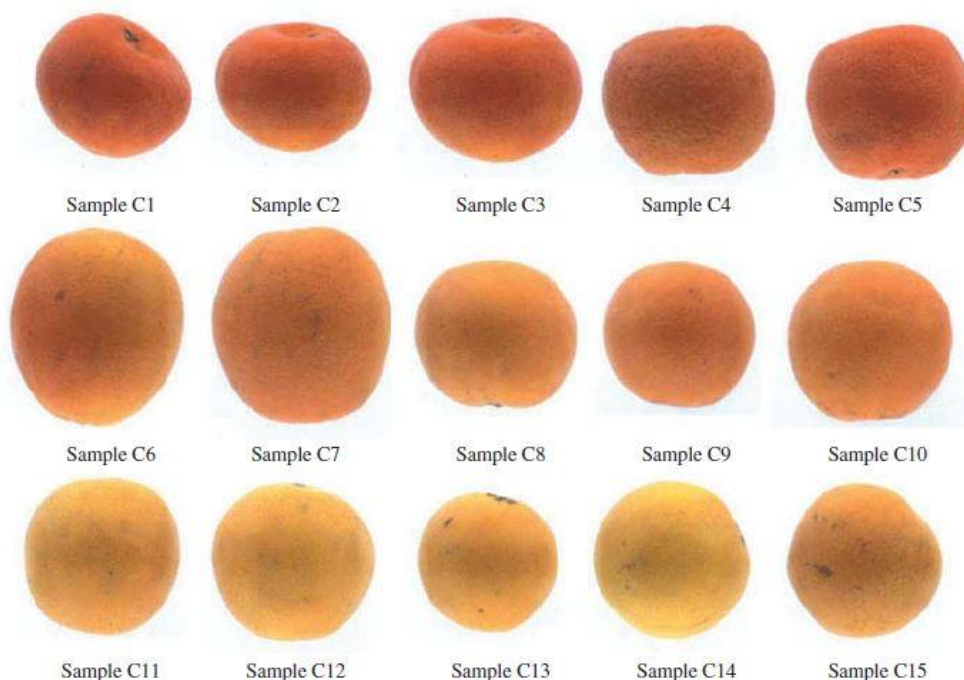

Sample of oranges

Later, R/G ratios and hue mean and median values of all sample fruits (oranges and sweet-limes) were acquired for further process.

The classification for oranges using R/G parameter is as follows-

- Oranges with value above 1.05 were classified as ripe,
- Oranges with values below 1.03 as unripe, and
- Oranges with values between the 1.03 and 1.05 as moderately ripe.

While the hue mean value for ripe fruits were less than 0.22, unripe above 0.24, and moderately ripe between 0.22 and 0.24. The hue median values for ripe fruits were less than 0.06, unripe above 0.09, and moderately ripe between 0.06 and 0.09.
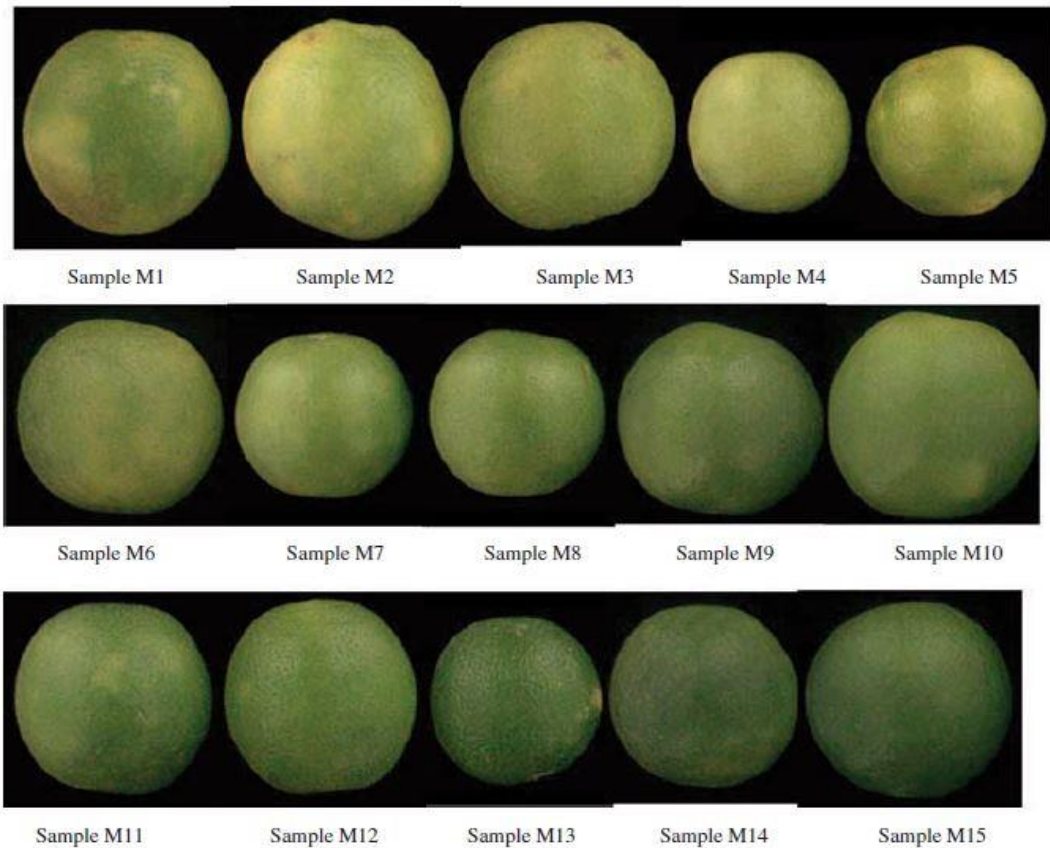
Sample of sweet-lime

Likewise, the classification for sweet-limes using R/G parameter is as follows-

- Sweet-limes with value above 0.95 were classified as ripe,
- Sweet-limes with values below 0.85 as unripe, and
- Sweet-limes with values between the 0.85 and 0.95 as moderately ripe.

Also for sweet limes, the hue mean value for ripe fruits were less than 0.22, unripe above 0.24, and moderately ripe between 0.22 and 0.24. The hue median value for ripe fruits was less than 0.19, unripe above 0.22, and moderately ripe between 0.19 and 0.22.

Orange fruits classification based on maturity

Sample number	R/G ratio	Hue mean	Hue median	Maturity
C1	1.0707	0.1448	0.0453	Ripe
C2	1.0652	0.1949	0.0467	Ripe
C3	1.0630	0.2149	0.0585	Ripe
C4	1.0548	0.2179	0.0586	Ripe
C5	1.0580	0.2115	0.0523	Ripe
C6	1.0396	0.2294	0.0657	Moderately ripe
C7	1.0401	0.2197	0.0716	Moderately ripe
C8	1.0362	0.2256	0.0812	Moderately ripe
C9	1.0349	0.2350	0.0800	Moderately ripe
C10	1.0384	0.2398	0.0818	Moderately ripe
C11	1.0266	0.2422	0.0931	Unripe
C12	1.0270	0.2467	0.0936	Unripe
C13	1.0293	0.2395	0.0959	Unripe
C14	1.0270	0.2400	0.1031	Unripe
C15	1.0265	0.2433	0.1043	Unripe

Classification of orange fruit on maturity

Sweet-lime fruits classification based on maturity

Sample number	R/G ratio	Hue mean	Hue median	Maturity
M1	0.9638	0.1910	0.1830	Ripe
M2	0.9976	0.2145	0.1732	Ripe
M3	0.9837	0.1795	0.1744	Ripe
M4	0.9989	0.1849	0.1688	Ripe
M5	1.0138	0.1731	0.1646	Ripe
M6	0.9484	0.2398	0.1923	Moderately ripe
M7	0.9015	0.2249	0.1993	Moderately ripe
M8	0.8909	0.2237	0.204	Moderately ripe
M9	0.8662	0.2335	0.2197	Moderately ripe
M10	0.8691	0.2286	0.2147	Moderately ripe
M11	0.8463	0.2455	0.2199	Unripe
M12	0.8441	0.2447	0.2208	Unripe
M13	0.7688	0.2501	0.2421	Unripe
M14	0.8355	0.3387	0.2462	Unripe
M15	0.7631	0.3014	0.2485	Unripe

Classification of sweet-lime fruit on maturity

Criteria for the maturity class

Parameter	Unripe	Moderately ripe	Ripe
Orange fruits			
R/G ratio	<1.03	1.03–1.05	>1.05
Hue mean	>0.24	0.22–0.24	<0.22
Hue median	>0.09	0.06–0.09	<0.06
Sweet-lime fruits			
R/G ratio	<0.85	0.85–0.95	>0.95
Hue mean	>0.24	0.22–0.24	<0.22
Hue median	>0.22	0.19–0.22	<0.19

Maturity class criteria

Matlab Code

```matlab
%%
%Select image
im=imread('apple.jpg');
imshow(im)

%%
%Extract colours

[row, col, other]=size(im);

midRow = abs(row/2);
midCol = abs(col/2);

r=single(im(:,:,1));
g=single(im(:,:,2));
b=single(im(:,:,3));

r=r(midRow-5:midRow+5,midCol-5:midCol+5);
g=g(midRow-5:midRow+5,midCol-5:midCol+5);
b=b(midRow-5:midRow+5,midCol-5:midCol+5);

r=sum(r(:));
g=sum(g(:));
b=sum(b(:));

%%
%Calculate euclidean distances and check colour of fruit
d1= ((r-255)^2+(g-0)^2+(b-0)^2)^0.5;
d2= ((r-0)^2+(g-255)^2+(b-0)^2)^0.5;

if d1<d2
    %Colour is Red
   color=1;
   disp('Fruit is red')
else
    %Colour is green
   color=2;
   disp('Fruit is green')
end

%%
%Edge calculation

r=single(im(:,:,1));
g=single(im(:,:,2));
b=single(im(:,:,3));

gr=rgb2gray(im);

if color==1
   d=r-single(gr);
else
   d=g-single(gr);
end

e=edge(uint8(d),'canny',0.4);
```

```
figure;
imshow(e)

[rw cl]=size(e);

for j=1:cl
    fl=0;
    for i=1:rw
        if e(i,j)==1
            sp=j;
            fl=1;
            break;
        end
    end
    if fl==1
       break;
    end
end

for j=cl:-1:1
    fl=0;
    for i=1:rw
        if e(i,j)==1
            ep=j;
            fl=1;
            break;
        end
    end
    if fl==1
       break;
    end
end

z=ep-sp;

%%
%Check for size
th=340;
if z<th
   sz=2;
   disp('Fruit is small')
else
   sz=1;
   disp('Fruit is big')
end
```