UNIVERSITY OF GAZIANTEP
GRADUATE SCHOOL OF
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DESIGN AND CONSTRUCTION OF A VISION SYSTEM FOR CHEESE QUALITY EVALUATION

M.Sc. THESIS
IN
MECHANICAL ENGINEERING

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ABDURAHMAN AYOUB
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Design and Construction of a Vision System for Cheese Quality Evaluation

M.Sc. Thesis
In
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Supervisor
Prof. Dr. Sadettin KAPUCU

By
Abdurahman AYOUB

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This is to certify that we have read this thesis and that in our consensus opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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Abdurahman AYOUB

ABSTRACT

DESIGN AND CONSTRUCTION OF A VISION SYSTEM FOR CHEESE QUALITY EVALUATION

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In the modern century, cheese plays a key role in many food factories. Over years, several methods of cheese quality evaluation have been devising, but unfortunately they are relying on the individual judgment of the tester. As a result, the lack of objectivity of the test methods motivates researchers and cheese-makers sought continuously to improve and maintain the quality of cheese. The purpose of this thesis is to design and construct a vision system to determine the melting characteristics of some commercial cheeses samples during heating, and ageing. In this research, Cheddar, Kashar and Mozzarella have been evaluated using a vision system which consists of an oven, a computer, a digital camera, a temperature controller, a data acquisition card, a thermal measurement system, a power supply, and a white tray. The principle work of the project has initiated with these tools. The oven temperature is controlled by PID controller. When the temperature of the oven is reached to the preset temperature, the sample is placed on the oven tray. The oven with top glass's cover allows the camera which is placed out of the chamber to capture image during melting process. At a certain interval of time, the images are captured and analyzed by using the proposed image processing algorithm to determine the area of the melting cheese sample. Melting characteristics of the Cheddar, Kashar and Mozzarella cheeses are then presented and the results are discussed. It is worth to mention, the device has good ability to be applied on the other food studies.

Keywords: vision system, cheese quality evaluation, characteristics of cheese meltability, digital image processing

ÖZET

PEYNİR KALİTESİNİN DEĞERLENDİRMESİ İÇİN GÖRÜNTÜLEME SİSTEMİ TASARIMI VE İMALATI

AYOUB Abdurahman
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Tez Yöneticisi: Prof. Dr. Sadettin KAPUCU
Ocak 2012, 120 sayfa

Modern yüzyılda, peynir gıda fabrikalarının birçoğunda önemli rol oynamaktadır. Yıllardır peynir kalitesinin değerlendirilmesi için birçok metot oluşturulmuştur fakat ne yazık ki bu yöntemlerin hepsi testi uygulayanın kişisel yorumlarına ve yargılarına bağlı kalmıştır. Sonuç olarak yapılan testlerin tarafsızlığındaki eksiklikten dolayı araştırmacılar ve peynir üreticileri peynir kalitesinin geliştirilmesi ve sürekliliğini sağlamak amaçlı çalışmalar yapılmıştır. Bu tezin temel amacı ticari peynir örneklerinin ısınma ve yaşlanma sırasında meydana gelen erime karakteristiğini ortaya koyan bir görüntüleme sisteminin tasarımı ve imalatıdır. Bu çalışmada Çedar, Kaşar ve Mozarella tipi peynirlerin karakteristiği fırın, bilgisayar, dijital kamera, sıcaklık denetleyicisi, veri toplama kartı, termal ölçüm sistemi, güç kaynağı ve beyaz tepsiden oluşan görüntüleme sisteminin kullanılmasıyla değerlendirilmiştir. Projenin temel çalışması bu araçların bir araya getirilmesi ile başlatılmıştır. Fırın sıcaklığı PID kontrolcüsü ile denetlenmiştir. Fırın sıcaklığı istenilen sıcaklığa ulaştığında numune fırın tepsisine yerleştirilmiştir. Peynirin erime işlemi fırının üst kısmındaki cam bölme üzerine yerleştirilen kamera ile görüntülenmiştir. Belirli zaman aralıklarında, görüntü yakalanmış ve erimiş peynir numunesinin erime alanın belirlenmesi için önerilen görüntü işleme algoritmasının kullanılmasıyla analiz edilmiştir. Çedar, Kaşar ve Mozarella peynirlerinin erime karakteristiği elde edilerek ve sonuçlar tartışılmıştır. Bu düzenek diğer gıda çalışmalarında da kullanılabilecek yetenektedir.

Anahtar kelimeler: görüntüleme sistemi, peynir kalite değerlendirilmesi, erime karakteristiği, dijital görüntü işleme

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ABBREVIATIONS

CCD:	Charged Coupled Device
CMOS:	Complementary Metal Oxide Semiconductor
DAQ:	Data Acquisition Card
RGB:	Red Green Blue Channels of Color Image
USB:	Universal Serial Bus
LOG:	Logarithmic Transformations
lt:	Liter
W:	Watt
cm:	Centimeter

CHAPTER 1

INTRODUCTION

1.1 Introduction and Research Objectives

Over the centuries, the dream of access technology serve humanity entices many of the scientists and researchers. Since their advantages and characteristics have ability to help the human within life stages. Image processing is one of the most important modern technologies had been discovered in the twentieth era. In 1960, image was processed technically with high cost for the first time. Due to this, image technology has been limited until 1971, when the computer revolution began to appear. Digital image processing played a key role in many areas of public and private life, such as cinema, document cleanup, photos enhancement, medical imaging, military application and factories. Scientifically, digital image processing is a number of computer algorithm that can be applied to manipulate and analysis the images for improving pictorial information. Typically, a major area of digital image processing is industrial inspection for automated visual inspection to control the quality and achieve the desired goal.

Over the past few years, the human inspection seeing and feeling were the quality assessment for food inspection. Investigate a computer vision technology has positive effectuation in the solution of controlling the processes, and collecting and analyzing the data. Many methods are invented and many ideas are appeared to construct a suitable method to evaluate the melt-ability of the cheese. In these methods, the cheese-containing foods are prepared at temperatures high enough for the cheese to melt and flow. Consumer preference and acceptance of such foods depend on the quality of melted cheese to a large extent. Thus, the characterizations of melting and flow properties of cheese are extremely critical for using cheese successfully as an ingredient. This requirement is becoming increasingly important as numerous kinds of cheese and cheese-containing food produces. Furthermore, to perform and apply these methods have requirements such as skills, time, and money.

The self-guiding style of this research is aimed to apply a digital image processing technique in food area. An automated cheese meltability test device was constructed to meet the following requirements:

- Quick: the test is to be conducted within a very short time.
- Easy: the test is to be conducted easily, without requiring undue demand on operate time and/or skills.
- Low cost: the test is to be performed fairly inexpensively.

1.2 Thesis Structure

Structure of the thesis has been organized in the way that reflects the steps followed. An automated cheese meltability test device is designed and built as follows:

In the first chapter, a brief history about the role of image processing technology is mentioned. Research objectives and the structure of the thesis are also given.

The second chapter is about the steps involved previously in the assessment of cheese using digital image processing technique.

The third chapter illustrates the importance and the purpose of each component used in construction of the device.

The fourth chapter explains and clarifies the algorithm structure used in the analysis and processing captured images.

The fifth chapter discusses the results and draws the conclusions. Finally it presents new ideas for future research.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

Generally, human inspection seeing and feeling are the quality assessment for food inspection. This method is costly, highly variables, and decisions are not always consistent between inspectors. However, the fundamentals of the technology, addressing the principles and techniques for image acquisition, segmentation, description, and recognition have been evinced. To date, machine vision has extensively been applied to solve various food engineering problems, ranging from simple quality evaluation of food products to complicated robot guidance problems.

In recent eras, rapid development in computer, software, and digital image processing led computer vision to be a unique technology for quality evaluation of diverse and processed foods. Physical characteristics like recognizing objects and extracting quantitative information are the common application for computer vision, which provides objective, rapid, non-contact, and non-destructive quality evaluation.

It is worth to mention, there are many methods that can generate image are used to examine and test food quality like thermal, ultrasonic, X-rays, and radio-waves technique. [1-4]

2.2 Quality Inspection of Cheese Products by Computer Vision

Cheese is a fermented product made from the milk of cows, goats, ewes, buffaloes and other mammals. Scientifically, cheese is a diary product made by separating the solid component of milk (curd) from the liquid part (whey) using cheese starters which play a role in defining cheese texture and flavor.

Over several thousand years, cheese manufacturing has advanced from an art to science. Due to its calcium, proteins and phosphorus contents, cheese has unprecedented popularity in many manufactured foods. Constantly, cheese-makers and researchers seek to improve and maintain the quality of cheese and cheese products. In the early of 1950s, a means of quality control has been realized by Arnott et al., 1957; Olson and Price, 1958. Over years, several methods of cheese quality evaluation have been devised, but unfortunately they are relying on the individual judgment of the tester. As a result, the lack of objectivity of the test methods motivates researchers and cheese-makers sought continuously to improve and maintain the quality of cheese. Furthermore, different categories like Microbial, physical, chemical, functional, etc are gathered under cheese quality assessment.

In the modern era, computer vision technique takes first place instead of human vision to analysis food with several advantages objectivity, consistency, speed of operation, cost-effectiveness, spectral perception, and preserves human from the risks operators. However, the quality properties which are measured by computer vision are mostly physical. Generally, size, shape, color, holes, etc., are the primary criteria which visibly change. Criteria have ranged from obvious surface feature like shape to dynamic analysis of evolving microstructure during processing like melting of cheese. [3, 4]

2.3 Fundamentals of a Computer Vision Technology

A vision system consists of an illumination, a camera, a frame-grabber, a computer, and a high-resolution color monitor. Normally, images which are acquired by camera have various defects. Sometimes these defects can be corrected by adjusting the acquisition hardware or/and treatment software. However, it is better to correct the images after have been acquired and digitized by using computer programs, which are fast and relatively low-cost. It can be achieved by several methods**;** like remove noise, smooth filters, and contrast enhancing. Such of these corrections in images are called 'image pre-processing'. After pre-processing, the main segmentation technique like thresholding, region, gradient, classification, watershed, and hybrid are used for recognition object of food products in the images. Over the years, size, shape, color, texture, or combined measurements are the object measurement methods for food quality evaluation. [1, 2, 5, 6] Figure 2.1 depicts image acquisition systems, image primitive operations, and object measurement types.

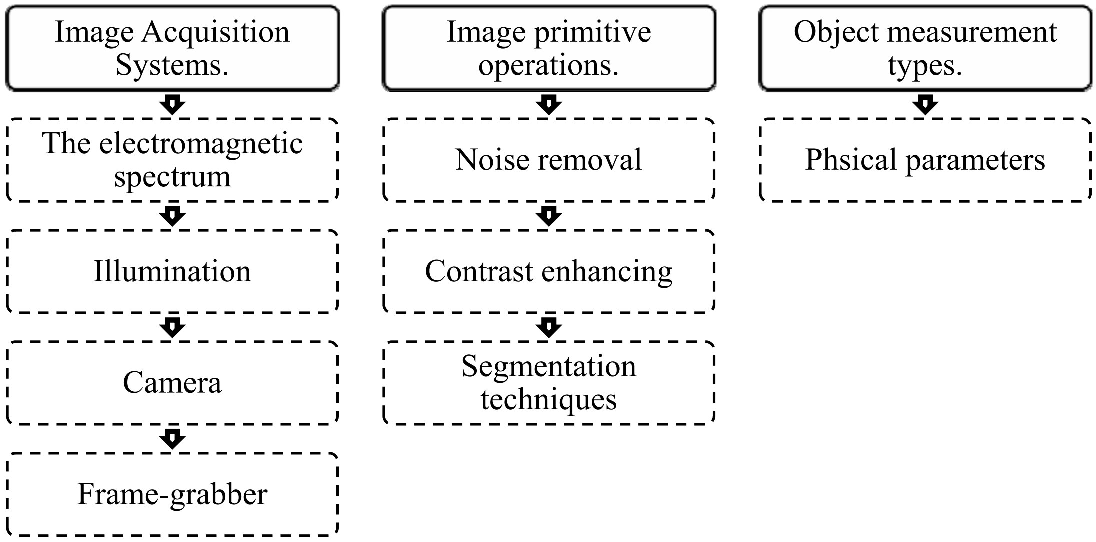


Figure 2.1 Main Parts of the Vision System and Basic Image Processing Techniques

2.3.1 Image Acquisition Systems

2.3.1.1 The Electromagnetic Spectrum

There are many forms of energy resources for creating images like ultrasound image, microscopy (Electron beams), Synthetic images, and Mechanic sensors. However imaging is based predominantly on the energy radiated by electromagnetic spectrum.

Scientifically, the term electromagnetic spectrum derives from a bunch of the electromagnetic radiation. Electromagnetic radiation is a form of energy has both electric and magnetic field components, which oscillate in perpendicular phase to each other and to the direction of energy propagation as shown in Figure 2.2.[1, 2, 6]

The electromagnetic spectrum is classified according to the frequency of wave, extended from the low frequency (Radio rays) to the high frequency (Gamma rays) as shown in the Figure 2.3.

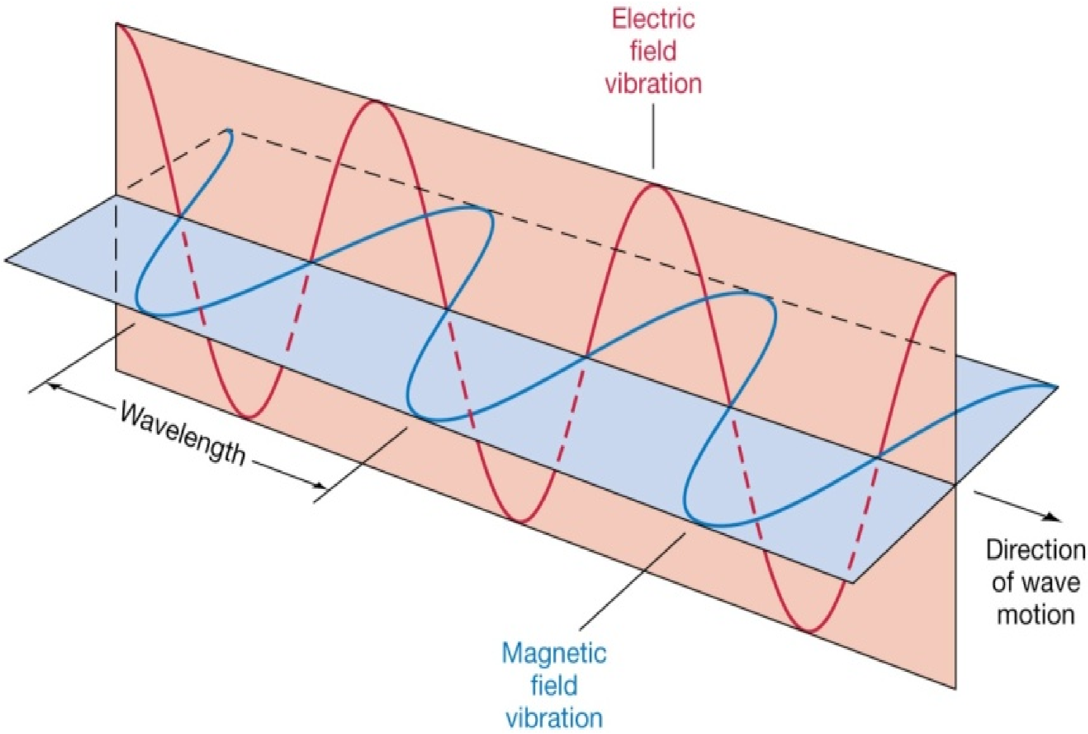


Figure 2.2 Plan of Electromagnetic Radiation Field [7]

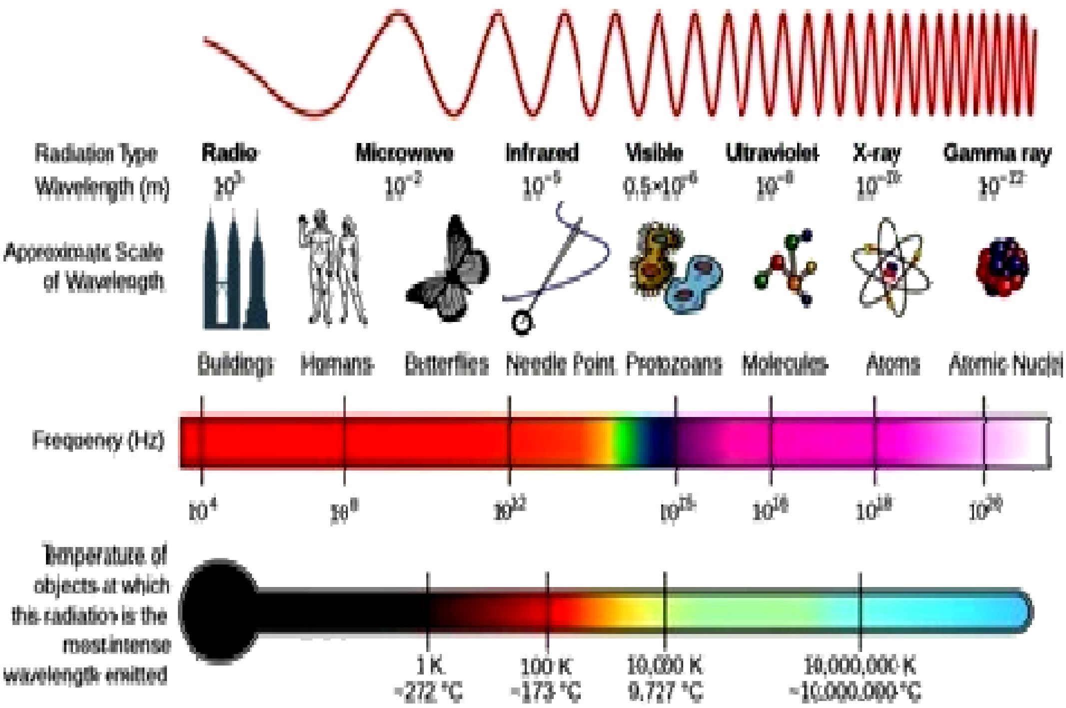


Figure 2.3 Electromagnetic Types [8]

2.3.1.2 Illumination

In the visual perception, illumination is one of the important elements of visual perception that determines failure or success of the imaging and machine vision system.

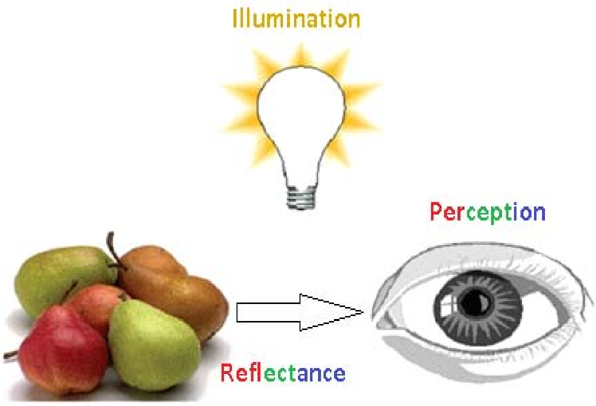


Figure 2.4 Simple Outline of the Human Perception Process

Appropriate lighting can improve the information of the image as shown in Figure 2.4. Scientifically, the scene reflects interaction of illumination, and the object with the vista point of the imaging system gives the intensity value of a pixel in the image.

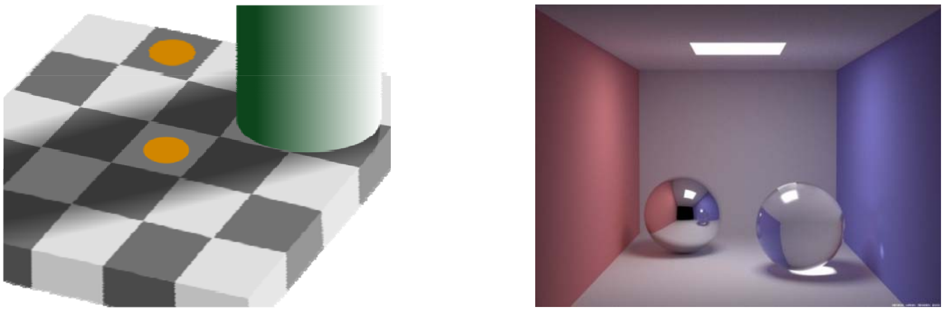


Figure 2.5 Effect of Illumination on the Surrounding [9,10]

Figure 2.5 displays the effect of the illumination. Generally suitable illumination is required for simple algorithmic methods, whereas defective illumination makes the algorithms unable to extract related features precisely. [1, 2, 5, 6]

2.3.1.3 Camera

In the world of high speed, camera is an appropriate device used in manufacturing or security systems, where has to be a way to look at course of conducting the operations. In digital image processing, camera is the first step to capture image electrically, where it converts photons to electrical signals as shown in Figure 2.6.

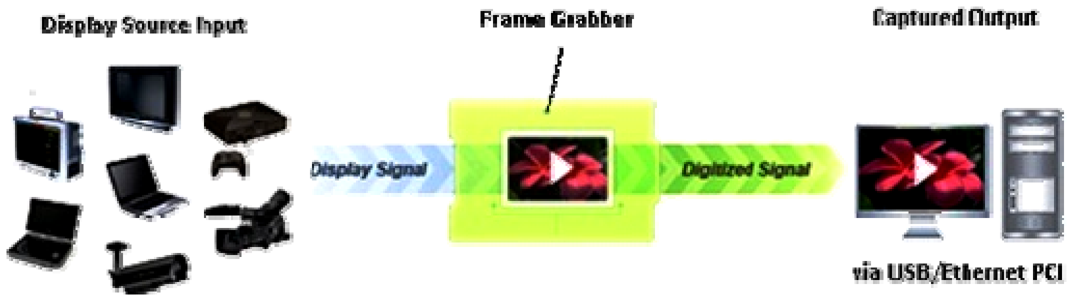


Figure 2.6 Main Steps of Capturing and Converting Images [11]

The camera has various types ranging from the older model like Vidicons to the recent design such as the Complementary Metal Oxide Silicon (CMOS) over the generations. In the 1970, the science of imaging sighted a huge revolution by innovation of the Charge Coupled Device (CCD). Generally, cameras work with one of the electromagnetic types as motioned above. [6]

2.3.1.4 Frame-Grabber

Coming signal from the camera is digitized and sent as a stream of data. This is second step of image capturing electronically. Scientifically, frame grabber is an electronic device which can seize and record a single frame out of the video stream and deliver it to a monitor, store it as a digital image, or a computer program for further analysis. Frame grabber is available in many forms, as a PCI or PCI Express board, or as an external interface with USB or Fire-wire interface.

Suitable frame grabber is basically selected depending on the camera's model, speed requirements, and computer specifications. Analog or digital frame grabbers are used with camera for control and PC interfacing. Analog type is an electronic device that is designed to turn the analog signal from analog camera into a digital signal that can be sent to computer for analysis, viewing and storage. Likewise, digital is used in digital camera. However, webcams have a frame grabber built-in, which they are typically connected to the computer via the USB port. [6]

2.3.2 Image Primitive Operations

Precisely, reading information, and transferring video signals from cameras to computers, and digitizing video signals lead to reduction in the quality of the images. As mentioned in Section 2.3 pre-processing technique can help to improve the quality of the images.

2.3.2.1 Noise Removal

Noise is extra electrical or electronic signals which are perturbation to a wanted signal, where it makes important or useful information difficult to be seen clearly. Each camera has a group of pixels consist of one or more photodiodes that convert photons into an electrical signal that give the color value of the pixel. In other words, explosion a pixel several times by the same amount of light which give imperfect values for color image have small statistical variations, called ‘noise’. Figure 2.7 depicts noisy image (left) and noise removed image (right)

In digital image processing, noise has several properties. It is visible in uniform surface and increases with temperature, sensitivity, length of exposure, and when a pixel size decreases. Noise is small information derived by sophisticated processing which makes an impossible event that can be determined.

However, researchers identified different types of noise like uniform surfaces (shadow), luminance noise (film grain), Amplifier noise (Gaussian noise), Salt-and-pepper noise, Shot noise, anisotropic noise, and color noise (color waves). In the other hand, scientist put the basic methods for removing noise from the image by using several filtering like linear, median, and adaptive filters. The type of the noise of the left image in Figure 2.7 is salt-and-paper noise. [1, 2, 5, 6]

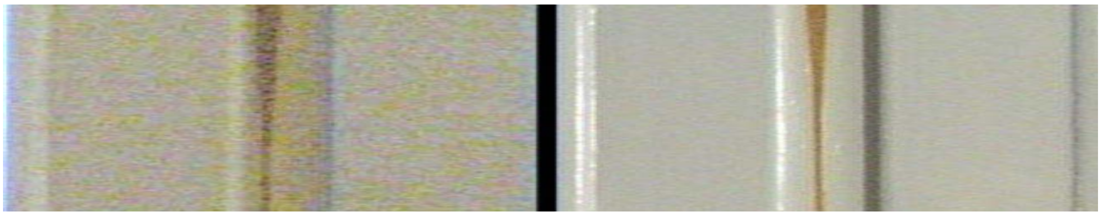
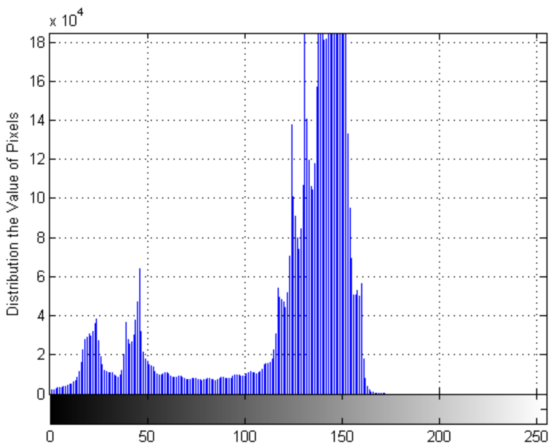


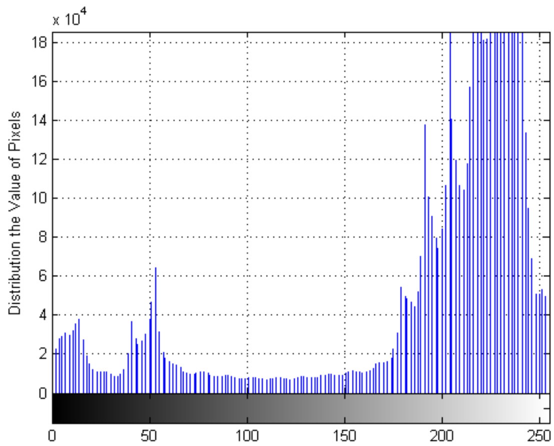
Figure 2.7 The Influences of the Noise on the Image [12]

2.3.2.2 Contrast Enhancing

Contrast enhances is one of the most important enhancing processes, which improves the noticeability of the objects by increasing the difference of the brightness values between background and their objects. Typically, contrast enhancement is done by contrast stretching of the brightness following by tonal enhancement. It improves the brightness in different regions like dark and gray levels. Practically, poor contrast results from one of the following reasons, lacking of illumination, insufficiency dynamic range in the image sensor, and wrong setting of the an opening holes which allows light to reach a lens. Linear and nonlinear types of digital techniques are used to increase the contrast of the image. Linear types include Min-Max, percentage, and Piecewise. On the other hand, nonlinear types contain histogram equalizations, Adaptive histogram equalization, Homomorphic, and Unsharp Mask filters. Figure 2.8 displays an example of contrast techniques of histogram equalization.



(a) Before Contrast Process



(b) After Contrast Process

Figure 2.8 Example of Contrast Techniques of Histogram Equation. X-axis Indicates Image Pixel Intensity

2.3.2.3 Segmentation Techniques

Image segmentation is partitioning of a digital image into different regions that makes image meaningful and easier to analysis. Typically, assigning a label to every pixel which belongs to a certain region sharing similar properties such as intensity, color, boundary and the texture is called as ‘segment’. Threshold, region-based processing, boundary detection, morphological and pixel intensity are the common techniques for image segmentation. [1, 2, 5]

2.3.3 Object Measurement Types

After segmentation technique, the objects are distinguished from the background which can allow calculating object’s characteristics. In digital image processing, the image is represented as a matrix; each element is called as ‘pixel’. These pixels infer two types of information; the location of pixels in the image called ‘geometrical information’ like size and shape, and the intensity values which is called ‘object surface’ like color and texture.

Mainly, size, shape, color and texture are the measurement objectives which contain significant information for food quality evaluation and inspection that can be obtained from images. Over time a huge number of methods for acquiring object measurement have been developed. However, choosing the correct object and merging with the others can help to prove food quality inspection. [1-5]

CHAPTER 3

DESIGN AND CONSTRUCTION OF THE COMPUTER VISION SYSTEM

3.1 Introduction

In every innovation, problems take a space in the research fields. Researchers try to overcome these problems by calling a new innovation or by using a suitable tool. Hopefully, choosing a device component according to required criteria can help to avoid and overcome early problems.

Technically, there are some problems while designing and constructing a computer .vision system to evaluate the melting characteristics of a cheese. For example, one of the problems is to detect cheese color on the tray. The color of the tray is also important. In an automatic and continuous operations search is to be done by computer and it must be reliable. Location of light, type of light, reflection of the tray, shadows of the installed camera, or the other objects may affect the color intensity of the captured image. Other problem is to keep the temperature of the oven at a predetermined value during experiments. Selection of the controller, gains, and type of temperature sensor may lead to substantial error in the determination of the temperature. Another problem is to select proper camera. Type of the camera image capturing principle and improper lens may cause distorted image. The problem due to the selected component of the machine vision system is to be solved and system is to be able to fulfill the requirements solution of the problems may be:

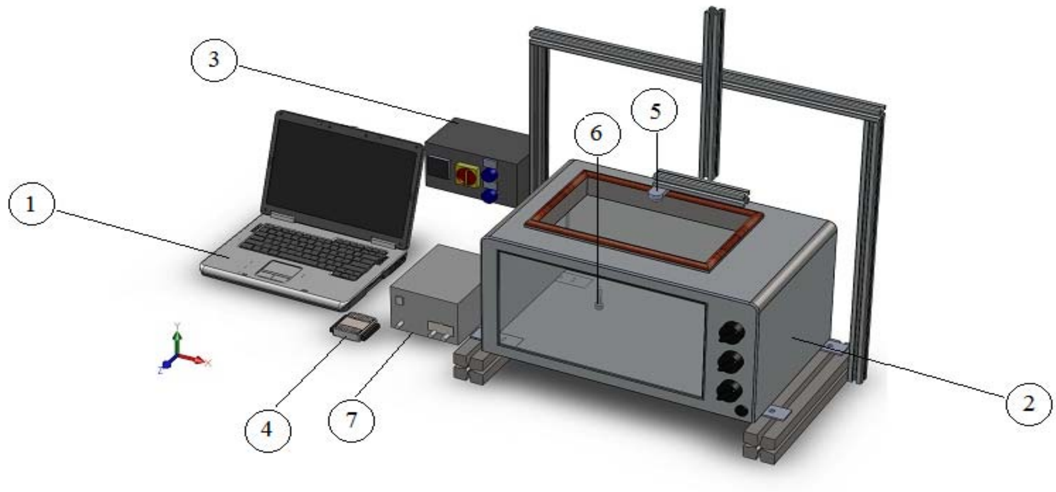
✐ Hardware-wise

- In the one side, hardware solution to avoid some problems by the cheaper and suitable tools opens a field to overcome and concentrate on other problems.

✐ Software-wise

- In the other side, software takes a widely side of solving almost problems, which can give you a positive result in the easy way without cost.

In this research, firstly suitable and/or available components of the system is collected and assembled as shown in Figure 3.1 and Figure3.2. Details of the components, working principle, and calibration if it is required are presented at the rest of this chapter.



1- Computer (Laptop Toshiba-L300-164 PSLBDE-005005AR)

2- Oven (Model: LUXELL, LX-3575)

3- Temperature controller (PID control / Model: DELTA)

4- Data acquisition tool (NI USB-6008)

5- Digital camera (Logitech - CCD)

6- Thermo measurement (TR-PT100)

7- Power supply (24 Volt)

8- White dish (Porcelain)

Figure 3.1 Computer Vision System to Evaluate the Cheese Melting Characteristics and Its Components

Figure 3.2 Photos of the Device from Workplace

3.2 Computer

Scientifically, a computer is a programmable machine designed to sequentially and automatically carry out a sequence of arithmetic or logical operations to solve more than one kind of problem. A Laptop, also called a ‘notebook’ which are used to read and treatment sequence of data by using a MATLAB program. Figure 3.3 shows main properties of the laptop used in this research.

Processor

- Type: Intel® Pentium® dual-core processor T2390
  Clock speed: 1.86 GHz
  Front Side Bus: 533 MHz
  2nd level cache: 1 MB

Graphics adapter

- Type : Intel® GMA X3100
  Memory amount : up to 358 MB total available graphics memory with 2 GB system memory
  Memory type : shared

AC adapter

- Input voltage : autosensing AC adapter (100/240 V) for worldwide usage
  Output voltage : 19 V
  Output current : 3.95 A

Display

- Size : 39.1cm (15.4”)
  Type : Toshiba TruBrite® WXGA TFT High Brightness display
  Internal resolution : 1,280 x 800

Figure 3.3 Specifications of the Computer [13]

3.3 Oven Characteristic

Conventionally, oven is a thermally insulted chamber or enclosed compartment used for roasting, backing, and heating food. Technically, convection oven cook food faster and more evenly than conventional oven. Typically, convection oven which is used have a general properties as shown in Figure 3.4.

Oven power: down = 1000 W.

Internal volume: 40 lt.

Turbo cooking feature

Product size: 48 * 59.5 * 33 cm

Figure 3.4 Properties of the Oven [14]

3.4 Temperature Controller (PID Control)

Control theory is an interdisciplinary branch of mathematics that deals with the basic principles underlying the design and analysis of control system. Practically, control means the influence value on the object’s behavior to achieve a desired goal by building a device that combines various mathematical techniques like Measure, compare, compute, and correct. In other words, control is a theory which deals with the behavior of dynamical systems for achieving stability. There are two types of control process systems open and close loop systems. Their block diagrams are shown in Figure 3.5.

Close loop controllers have advantages over open loop controllers that improve the problems of the open loop controller, where can be summarize some important advantages:

- ✐ Flexible

  Work with the all models perfectly even variable models that environment parameters are not fixed.

✐ Stability

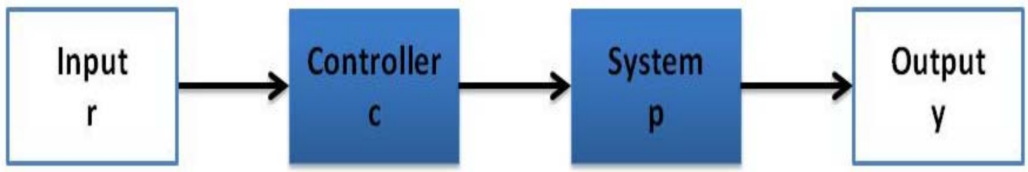
Make the unstable process stable within time.

✐ Effectiveness

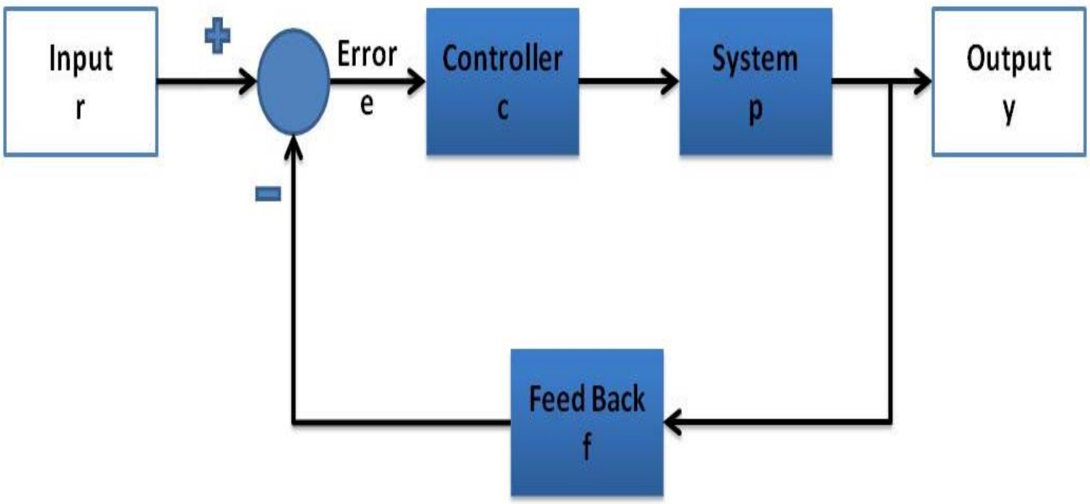
Control the effectuation of the variations parameter, where the system moves around the desire value.

✐ Performance

Improve the reference value.



(a) Open Loop System



(b) Close Loop System

Figure 3.5 Open and Close Loop System Block Diagrams

3.4.1 PID Controller

In 1922, Minorsky invented a new architecture named ‘PID controller’, which is an acronym for Proportional-Integral-Derivative. PID or what called ‘three term controller’ is the common structure used for achieving desire value, implementing set point changes and cancelling unwanted disturbances by adjusting the three parameters (K_p, K_i, and K_d), which they are defined by following equations:

(3.1)

(3.2)

Where:

e: Error = Set point (r(t)) – Process value (y(t))

t: Time or instantaneous time

Ti: the controller's integrator time constant

Td: the controller's derivative time constant

The form of the PID algorithm is shown in Figure 3.6.

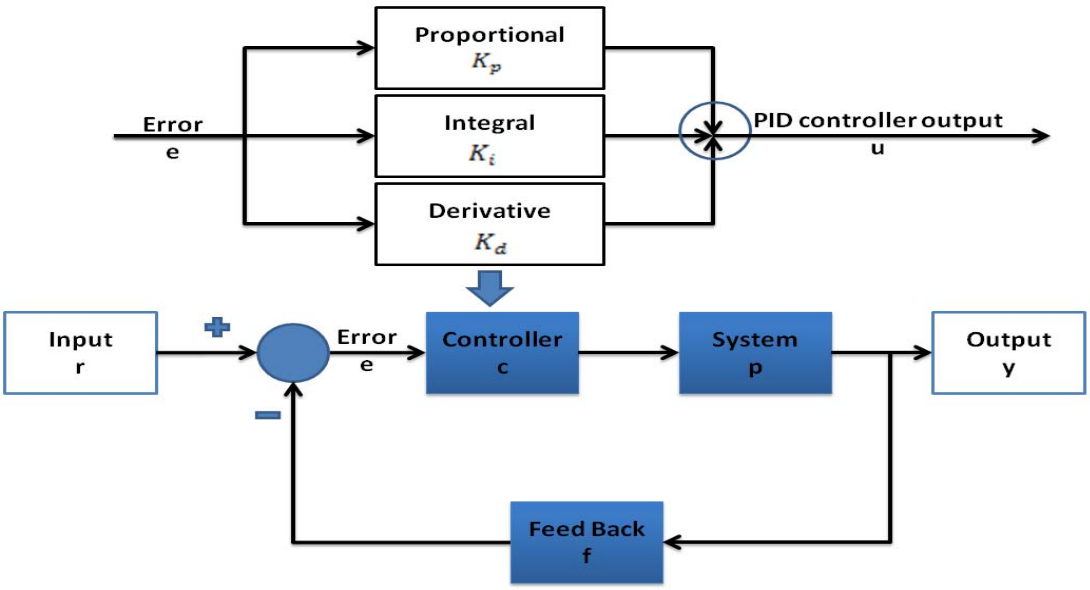


Figure 3.6 Schematic of PID Controller

3.4.2 Calculation of PID Parameters

To find the suitable parameters for tuning the PID controller is so difficult if the mathematical model parameters of the system are unknown. However, experimental method may provide system constants so that the system can be approximately modeled. It is well known that a temperature sensor subjected to set point temperature is defined by following equation:

$$\frac{1}{\tau s+1} e^{-T_d s} \tag{3.3}$$

Where:

τ: time constant

T: delay time

It is necessary to obtain the system response curve to calculate the response time. After that time constant value and delay time can be evaluated from it mathematically. [15]

The temperature measurement device integral and derivation gains are set to zero but on the contrary proportional gain is set to high value. Actual temperature value, T_o, is set to 190^{o}c. then, temperature, T(t), and corresponding time, t, is recorded as shown in Table 3.1 and plotted in Figure 3.7. Time response, τ, shown in Table 3.1, can be calculated by following equation:

$$\frac{T(t) - T_\infty}{T_0 - T_\infty} = e^{-\frac{t}{\tau}} \tag{3.4}$$

Where:

T (t): Measured temperature

T_∞: Environment Temperature

$T_\circ$: Set temperature = 190

t: Time response

Table 3.1 Calculating Time Constant Values

Temperature T(t)	Time response (seconds) t	Time constant τ	Time response (seconds) t	Temperature T(t)	Time constant τ
22	0	3353.419	110	360	527.879
25	57	1819.916	115	383	518.175
30	87	1397.714	120	410	512.655
35	104	1163.12	125	437	505.614
40	124	1011.864	130	465	498.238
45	140	905.64	135	499	495.336
50	155	829.066	140	539	495.659
55	170	766.216	145	584	497.253
60	184	719.687	150	649	511.119
65	199	677.806	155	729	530.135
70	213	647.862	160	832	557.303
75	229	621.367	165	964	592.707
80	245	597.457	170	1131	635.184
85	261	575.520	175	1302	663.301
90	277	558.899	180	1561	714.072
95	295	546.293	185	1944	758.856
100	315	535.111	190	2514	873.159
105	336	535.111			

When the successive values of the time constant are examined it is found that the successive four values are almost the same value. This indicates that time constant will be the value of 495.336. Delay time is the period of time accounted after turning the device on directly until change happened to the temperature. The device delay time is measured as 27 seconds.

Substituting the delay time and time response into equation 3.3, the mathematical model of the device becomes:

(3.5)

Figure 3.8 shows the response of the equation 3.5 with the PID gains.

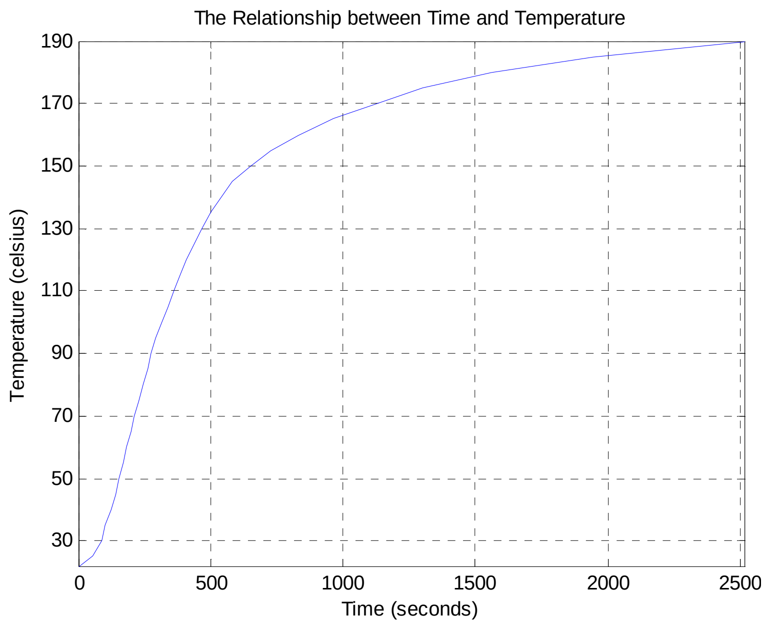


Figure 3.7 The Response of the Experimental System

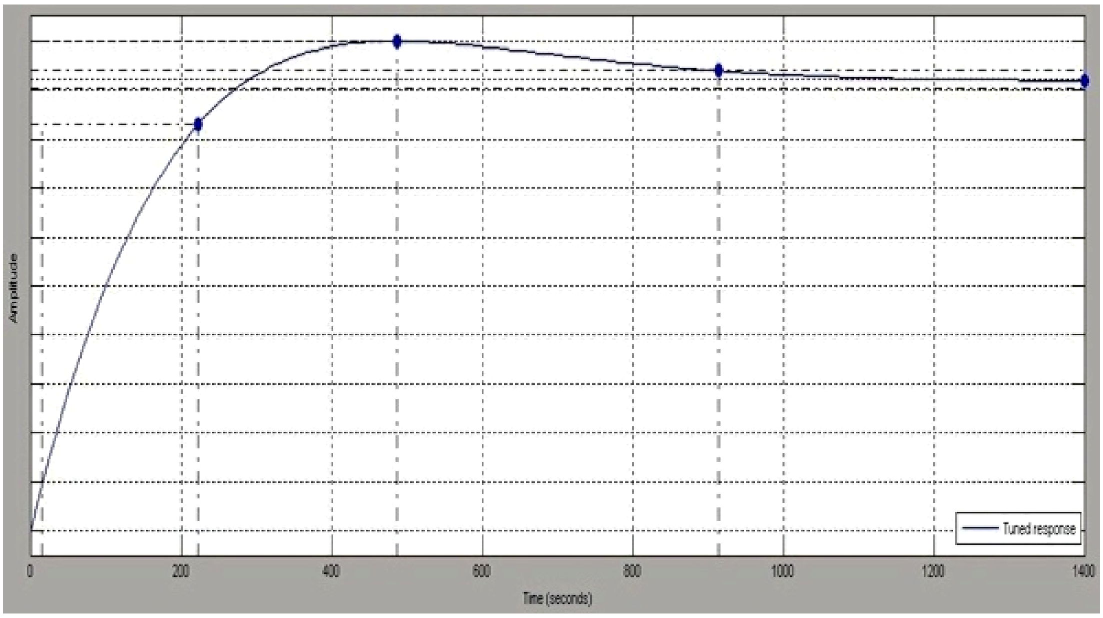


Figure 3.8 The Response of the mathematical model of the device (equation (3.5)). PID gains are; Proportional Value=26, Integral Value=309, and Derivate Value = 11

3.5 Data Acquisition Tool

Data acquisition system which is abbreviated with the acronym DAS or DAQ, is the process of copying and recording parts of signals measured in the physical conditions as an electronic form and converting into a digital output. It is operated by a computer. Generally, data acquisition systems include:

- Converter

  Which converts the physical parameters to electrical signals called ‘sensor’.

- Signal

  Conditioning circuit converts sensor signals into a readable form.

- Analog – digital converter

  Converts the readable data to digital values.

Then these digital signals are controlled and conducted by software programs like MATLAB, and LABVIEW which they are developed using various programming languages like C, BASIC, FORTRAN, JAVA, and Pascal. Table 3.2 shows the properties of the data acquisitions device used:

Table 3.2 Specifications of Data Acquisition Device [16]

General	Product	Measurement Type
	• USB-6008 Data Acquisition	• Voltage
Analog Input	Channels	Voltage Range
	• 4 , 8	• -10 V , 10 V
Analog Output	Channels	Voltage Range
	• 2	• 0 V , 5 V
Digital I/O	Number of Channels	Input and Output Range
	• 0 , 12	• 0 V , 5 V

3.6 Camera and Digital Camera

Camera and digital camera idioms have two different meaning. One conventionally meaning, where camera is a device for recording an image of an object on a light-sensitive surface called ‘film’, which image is inflexible for modification. On the other hand, digital camera that captures images electronically rather than on film can be modified using suitable programs such as LABVIEW, MATLAB, PHOTOSHOP, etc.

3.6.1 Digital Camera and Image Sensor

In the digital camera, the image is captured by array sensors, stored in the camera's random access memory or a special diskette, and transferred to a computer for modification, long-term storage, or printing out. Since the technology produces a graphics file, the image can be readily edited using suitable software like MATLAB. In the 1996, digital camera models are designed and produced for the first time to users who want to send pictures over the Internet or to crop, combine, enhance, or otherwise modify their photographs.

An array sensor or an image sensor is a device that converts an optical image into an electronic signal. It is used mostly in digital cameras and other imaging devices. Camera are evolved over time, from the early type which is video camera tubes to modern types like a charge-coupled device (CCD) and a complementary metal–oxide–semiconductor (CMOS) active pixel sensor. Both types of sensor accomplish the same task of capturing light and converting it into electrical signals but in different processes. CCD and CMOS sensors perform the same steps, but in different locations, and in a different sequence. However, the main work for the two types is to convert the light to charge then accumulate it. Photo sensor is the light sensitive region of pixel as shown in Figure 3.9.

In the principle work and formation, A CCD image sensor is an analog device, when light strikes the chip a small electrical charge held in each photo sensor. Afterwards, charges are converted to voltage on a pixel at the time are reading from the chip and send it by vertical and horizontal CCD channels to amplifier behind horizontal CCD as shown in the Figure 3.10. Additional circuitry in the camera converts the voltage into digital information.

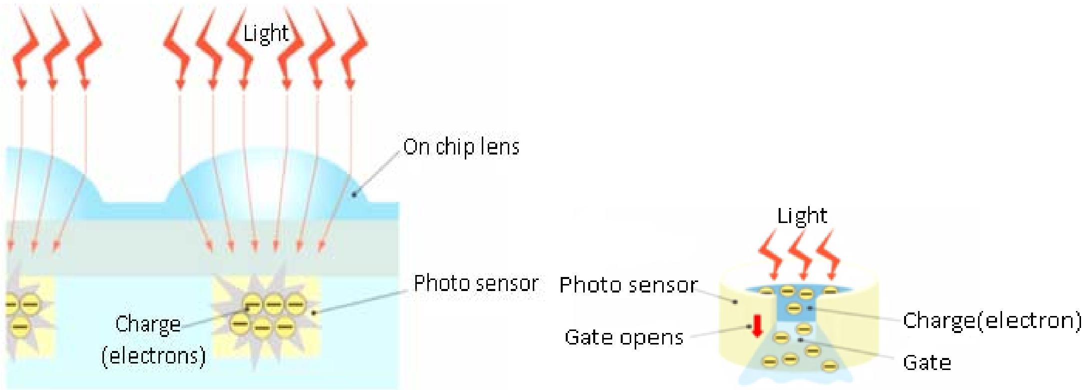


Figure 3.9 Schematics of a Photo Sensor [17]
(Convert Light to Charge and Accumulate it)

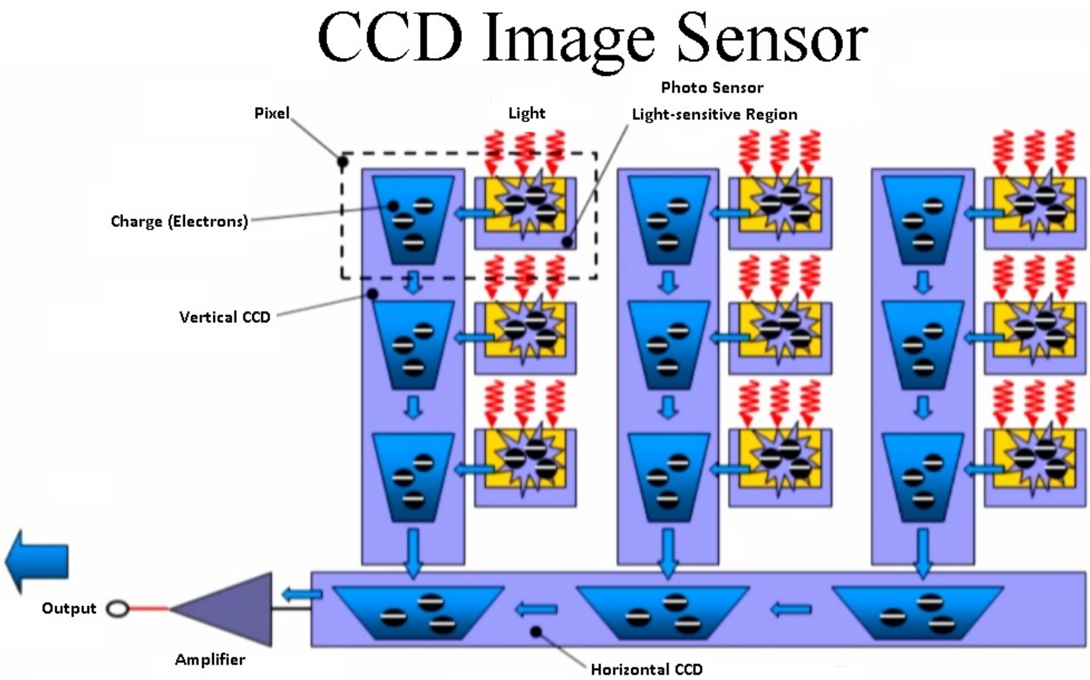


Figure 3.10 Plan of CCD Sensor Formations [17]

While, a CMOS is an image sensor consisting of an integrated circuit containing an array of pixel sensors, each pixel contains a photodetector and an active amplifier. Where it converts to voltage and amplified it within pixel, and then transfers by signal wire (micro wire) as shown in the Figure 3.11. Additional circuitry on the chip may be included to convert the voltage to digital data.

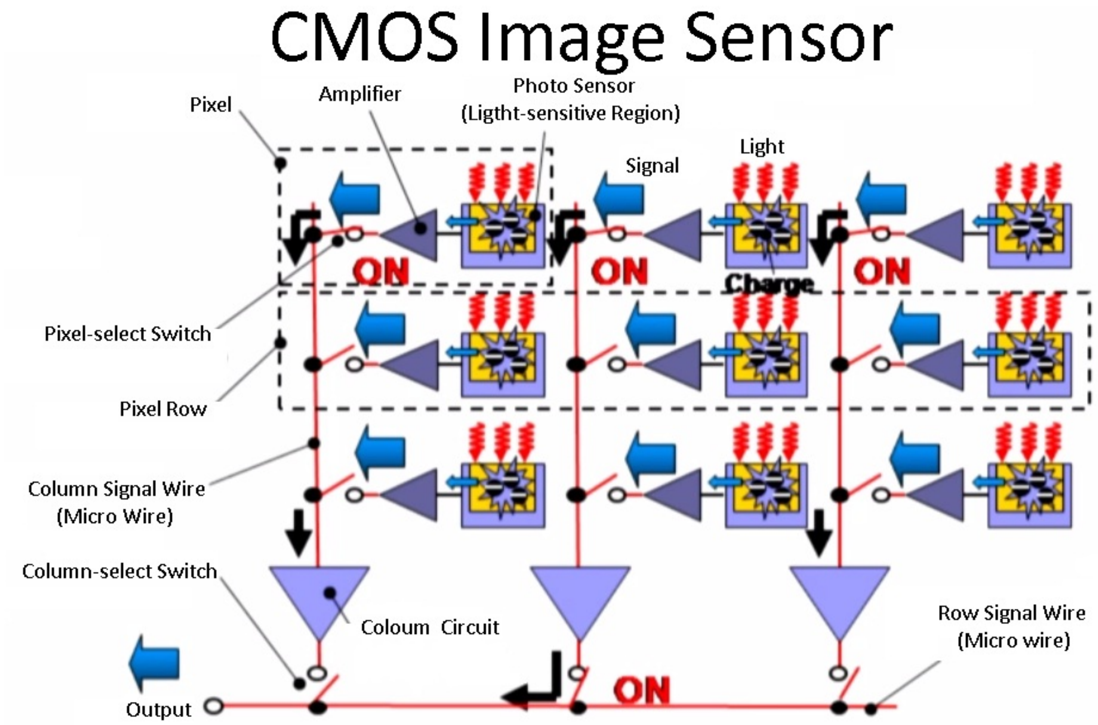


Figure 3.11 Plan Of CMOS Sensor Formations [17]

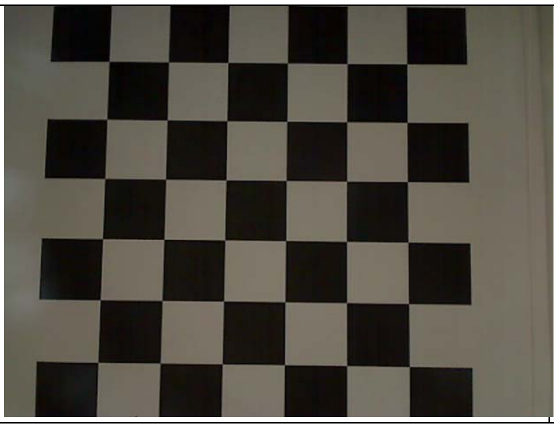
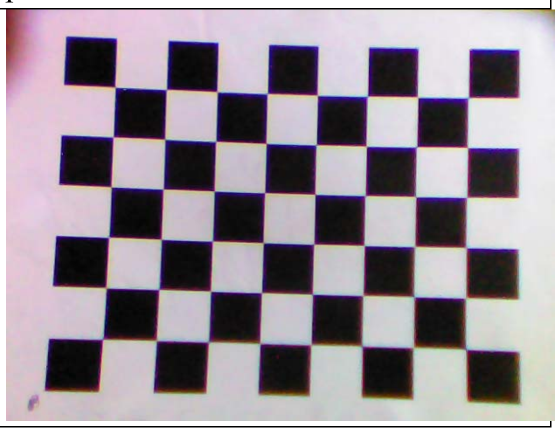
However, the quality of image for CCD sensor is more susceptible to vertical smear than CMOS sensor from bright light source when the sensor is overloaded.

Per contra, CMOS sensor is susceptible to undesired effects that come as a result of rolling shutter. Rolling shutter or known as line scan is a method of image acquisition in which each frame is recorded not from a snapshot of a single point in time, but rather by scanning across the frame either vertically or horizontally. Moreover, it is affected by the noise within send the charge by the micro wire.

Finally, it is worth to mention that hybrid CCD/CMOS architecture, sold under the name "sCMOS". However, hybrid sensors are still in the research phase. [6, 17]

Table 3.3 summarizes important differences between CCD and CMOS sensors:

Table 3.3 Comparison between CCD- and CMOS- Sensors

Charge-Coupled Device (CCD)	Complementary Metal–Oxide Semiconductor (CMOS)
Signal out of Pixel	
Electron	Voltage
Signal out of chip	
Voltage(analog)	Bits(digital)
Signal out of camera	
Bits(digital)	Bits(digital)
Amplifier mismatch	
N/A	Moderate
System noise	
Low	Moderate
System complexity	
High	Low
Sensor complexity	
Low	High
Cost	
CCD sensor's is more expensive than CMOS sensors.	CMOS sensors are less expensive to manufacture than CCD sensors.
Implementation	
CCD is a more mature technology and is in most respects the equal of CMOS.	CMOS can potentially be implemented with fewer components, use less power, and/or provide faster readout than CCDs.
Example	
	

3.6.2 Camera Calibration

3.6.2.1 Pinhole Camera

The explanation of the idea of entry the force of sunlight through trees papers or holes was occupied the minds of scientists. Prior to 1485, it was just a manuscripts mimic the idea of the pinhole. In 1485, the Italian artist and inventor Leonardo da Vinici for the first time described with detailed a pinhole. Pinhole camera, camera obscura, or dark chamber known as a closed box has a small hole in one of its side, which implementation the basic of the optical image. However, this idea has still just ink on paper until 1850, when the Scottish scientist Sir David Brewster has succeeded to take the first photograph with a pinhole camera. In the pinhole camera, the rectilinear propagation of the reflection rays of light from every point on the surface of an illuminated object is the principle for creating an image. In 1891, Lord Rayleigh has published the formula that calculates the optimal diameter of the hole in order to achieve a sharpest image as show in Figures3.12.

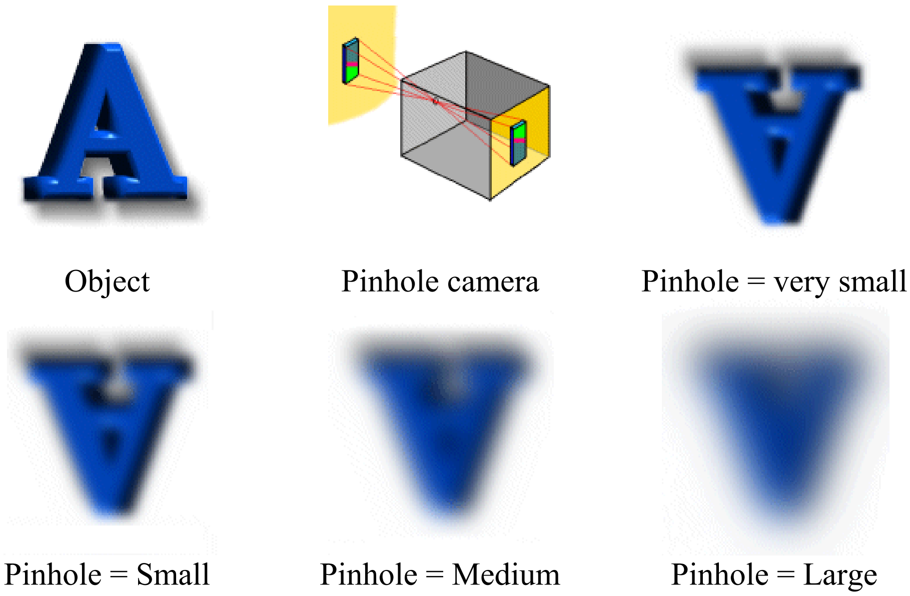


Figure 3.12 The Influence of Pinhole Size on Sharpening Image [18]

Through the eras, the dark chamber ideas quickly evolved, and the pinhole camera model become the basic of the relationship between a 3D point in the world coordinate and its 2D point projection onto the image plane.

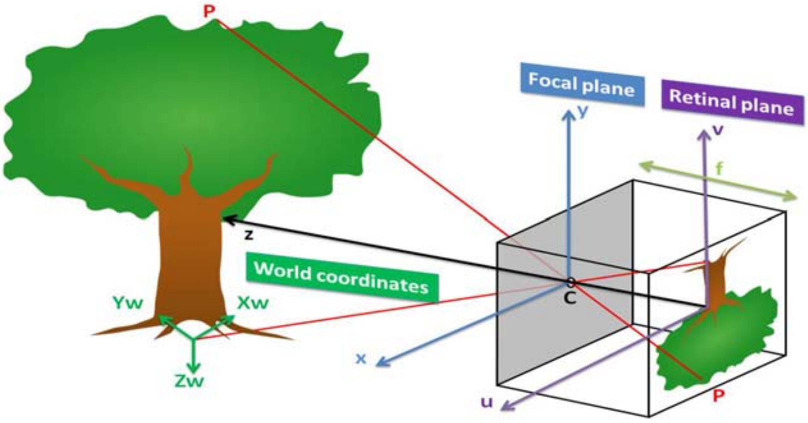


Figure 3.13 The Relationship Between 3D World- and Image- Coordinates [19]

Dark chamber consists of two parallel planes, retinal- and focal- plane, where they are separated by the distance f called 'focal length'. Each plane has a property, retinal or what called 'image plane' is the plane where the image is formed, while the optical center C is in the middle of focal plane identify the sharpness of the image as shown in Figure 3.13. [6, 19]

3.6.2.2 Physical Camera Parameters

Camera calibration is the process of finding: intrinsic- and extrinsic- parameters, which describe the mapping process from a 3D world's coordinate to a 2D image's coordinate. Geometrically, optical characteristics are representing by the intrinsic or internal parameters, while extrinsic parameters represent the relationship between the certain world coordinate system and, 3-D position and orientation of the camera frame. Camera matrix is the result of multiplying the internal and external parameters.

Theory to map any point like P, there is a need to transform it from the world coordinate (X_w, Y_w, Z_w) to the focal or camera coordinate (x, y, z) by calculating the extrinsic parameters T_e, where it represents the position of the camera center and camera's heading on world coordinate. Figure 3.14 depicts the relationship between the world coordinate (X_w, Y_w, Z_w), camera coordinate (x, y, z), and image coordinate (u, v, s). Calculating the translation t_i and r_{ij} rotation matrix of the point P gives the T_e matrix:

$$T_e = \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \tag{3.6}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = T_e \ x \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \tag{3.7}$$

Where:

(x, y, z): the camera coordinates

(X_w, Y_w, Z_w): the world coordinate

Te: the extrinsic parameters

ti : the translation matrix

rij : the rotation matrix

Afterwards, via calculating the focal length f, the principle point (u_o, v_o), the scale factor, and the principle point, which they represent the internal parameters T_i matrix, the point P will be transformed from focal plane to the retinal plane.

$$T_i = \begin{bmatrix} \propto & 0 & u_o \\ 0 & \beta & v_o \\ 0 & 0 & 1 \end{bmatrix} \tag{3.8}$$

$$\begin{bmatrix} u \\ v \\ s \end{bmatrix} = T_i \ x \begin{bmatrix} x \\ y \\ z \end{bmatrix} \tag{3.9}$$

Where:

(u, v, s): the retinal coordinate

(u_o ,v_o): the center of the image plane

$\alpha = f/k_o$

$\beta = f/k_1$

(k_o, k_1): the pixel size in mm.

f: the focal length.

Camera matrix is a result of multiplying T_e and T_i, which it represents the transformed process from 3D reference coordinate onto a 2D image plane. [20, 21]

(3.10)

The MATLAB camera calibration toolbox is employed to calibrate the both intrinsic and extrinsic parameters and camera matrix. To do this process a chess board pattern as shown on the bottom of the Table 3.3 is used the intrinsic parameters, the extrinsic parameters and the camera matrix are given in equation (3.11), equation (3.12), and equation (3.13), respectively.

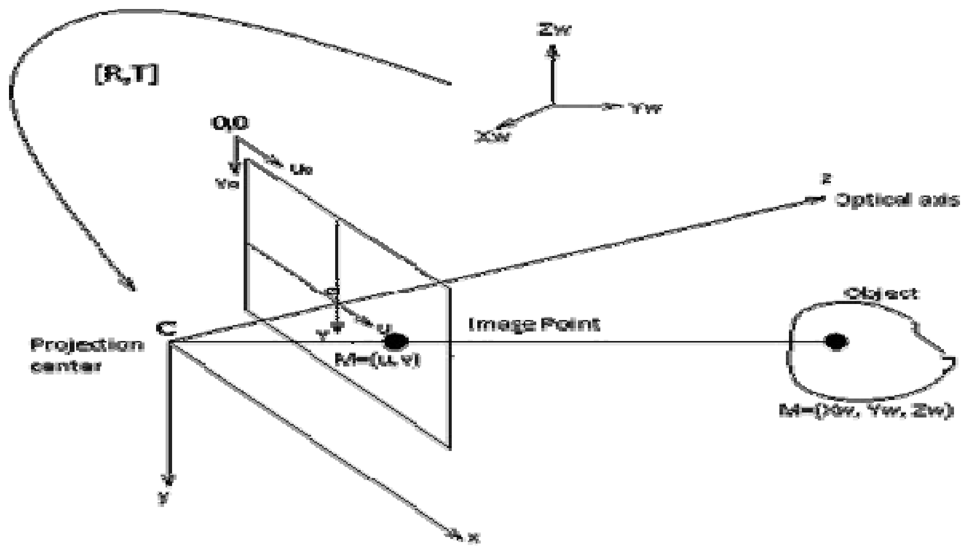


Figure 3.14 The Relationship between World-, Camera- and Retinal- Coordinates

(3.11)

(3.12)

(3.13)

3.7 Thermal Measurement and Signal Converter

Temperature is a physical property of matter which expresses the common concept of hot and cold. Most of the measuring temperature methods relay on measuring physical property of a working material. Within the years, many methods have been developed for measuring temperature like thermocouples, glass thermometer, and resistance temperature detector (RTD). Typically, PT100 or which is called ‘platinum resistance thermometer’, a type of resistance temperature detector sensor is used with a signal converter TR-PT100. Figure 3.15 and Table 3.4 show the image and the specifications of the TR-PT100 converter, and PT100 temperature sensor respectively.

Table 3.4 Thermal Measurement and Signal Converter Properties [22]

Type: TR-PT100 converter	Type: PT100 sensor, temperature sensor
OUTPUT: 4-20mA/2-10V	Diameter: 4mm / 6mm
ACCURACY : +/-0,2C degree	Wire Length : 1m
RANGE : 0-200C degree	Temperature range: -200 C to 420 C

(a)

(b)

Figure 3.15 (a) TR-PT100 Signal Converter, and (b) PT100 Temperature Sensor

The name PT100 combined from two abbreviation letters; one is PT which indicated the material made from (platinum). Others, is sign to the resistance of the platinum at 0^{o} C (100 ohms).

3.7.1 PT100 calibration:

As mentioned above TR-PT100 is a signal converter, which converts ohm values to voltage or current analog signals can be measured using computer by converting it to digital signal. Data acquisitions tool which convert voltage analog signals to digital readable signals by computer using MATLAB software. To find the relationship between the voltage and the temperature, another thermo-measurement used. Mercury thermometer or what called 'glass-thermometer' is used for calibrating PT100 sensor.

Figure 3.16 PT100 Calibration Process from the Workplace

As shown in the Figure 3.16, PT100 sensor and glass thermometer put together in the same basin which contains water. During the boiling process of water, reading and recording temperature from glass thermometer and voltage signals from TR-PT100 was done by computer using MATLAB. The outcome is a linear relationship which is represented in the equation:

$$y\ (a_1, a_2, x) = a_1 * x + a_2 \quad (3.14)$$

Where:

$a_2 = 0.9782$

$a_1 = 0.01986$

Figure 3.17 shows the relationship between temperature versus voltage. A linear relationship exists as expected.

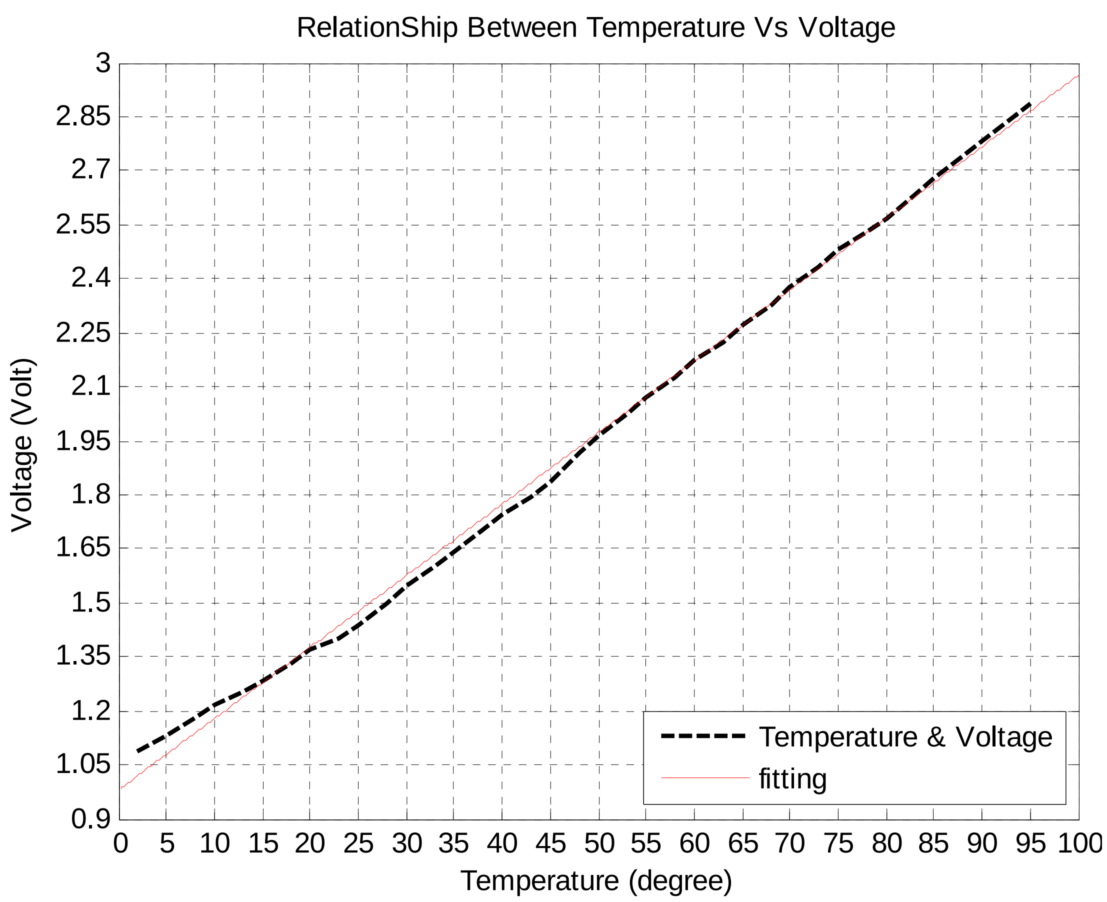


Figure 3.17 Relationship between Temperature and Voltage

3.8 Choosing Tray Color

Chromatology is the science of color which includes the perception of color by the human eye and brain, the origin of color in materials, color theory in art, and the physics of electromagnetic radiation in the visible range.

In the field of chromatology, color is the visual perceptual property corresponding in humans to the categories called red, green, blue and others as shown in Table 3.5. Color derives from the spectrum of light interacting in the eye with the spectral sensitivities of the light receptors. Color categories and physical specifications of color are also associated with objects, materials, light sources, etc., based on their physical properties such as light absorption, shadow, reflection, or emission spectra. By defining a color space, colors can be identified numerically by their coordinates.

Because perception of color stems from the varying spectral sensitivity of different types of cone cells in the retina to different parts of the spectrum, colors may be defined and quantified by the degree to which they stimulate these cells. These physical or physiological quantifications of color, however, do not fully explain the psychophysical perception of color appearance. [23, 24]

Table 3.5 The Colors of the Visible Light Spectrum [23]

color	wavelength interval	frequency interval
red	~ 700–635 nm	~ 430–480 THz
orange	~ 635–590 nm	~ 480–510 THz
yellow	~ 590–560 nm	~ 510–540 THz
green	~ 560–490 nm	~ 540–610 THz
blue	~ 490–450 nm	~ 610–670 THz
violet	~ 450–400 nm	~ 670–750 THz
white	~ 700 -400 nm	~ 430–750 THz

3.8.1 Effect of the Colors

Generally, the physics of the object in its environment and the characteristics of the perceiving eye and brain; identifies the features of object's color. Physically, depends on the spectrum of the incident illumination, the reflectance properties of the surface, and potentially on the angles of illumination and viewing; objects, can be said to have the color of the light leaving its surfaces. Moreover, some objects contribute to the color by not only reflect light, but also transmit light or emit light themselves. However, a viewer's perception of the object's color depends not only on the spectrum of the light leaving its surface, but also on a host of contextual cues. As a result of that, the color tends to be perceived as relatively constant or what is called as 'color constancy', this effect mean relatively independent of the lighting spectrum, viewing angle, etc. [23, 24]

Draw some physical phenomena away from the perception of Figure 3.18:

- Light arriving at an opaque surface is either reflected like specularly, scattered, absorbed, or some combination of these.
- Opaque objects which have rough surface do not reflect specularly. Their color determined by which wavelengths of light scatter more and which scatter less. Furthermore, if objects scatter all wavelengths, they appear white. If they absorb all wavelengths, they appear black.
- Objects transmit light via two way, scattering the transmitted light where called 'translucent' or by transparent which not scattering the transmitted light. In some cases, they appear tinted with a color determined by the nature of reflection or absorption of light of varying wavelength.
- Giving objects ability to emit the light rather than merely reflect or transmit it, happens maybe because of increasing temperature where this phenomenon called 'incandescent' or for other reasons.
- Fluorescent and phosphorescent phenomenon is a result of absorbing object for the light and emits it with different properties. Where emitting white light called 'fluorescent', while phosphorescent refer to emitted light even after stop absorption or the light emitted because of chemical reaction.

To put in a nut shell, the properties of the surface of the object identify object's color. Acquired color of the object is the effect of transmission, emission, color constancy, ambient illumination and characteristics of the eye and brain.

Figure 3.18 The Influence of Colors

3.8.2 The Effect of the Tray Type on the Image

Four different trays are used during tests as, Pyrex-, Black iron-, White Porcelain- and Silver Aluminum- tray.

i. **The Pyrex-tray,** the translucent or transparent of the glass has given the cheese tinted with a color determined by the nature of its absorption (or reflectance). On the other side, since the cheese is a semi-rough and opaque, light arriving at cheese surface is either reflected, or absorbed or some combination of these, in the way that the reflection or absorption was act as a light (figure 3.19(a)).

ii. **The black iron-tray,** the black color and spangle of the surface has given cheese a whiteness surface. The opaque of the cheese, darkness- and spangle- of the tray's color aid increases the reflection of the cheese and decreases the absorption. Note, that cheese scatters almost all wavelengths, so it's appear to be white. Since cheese will change color from orange near to dark brown or black within cook it, cheese will be embedded in the black color (Figure 3.19(b)).

iii. **The Silver Aluminum-tray,** the cheese got a semi-natural color where aluminum works like Pyrex. Moreover, silver absorbed some of the light that decreases the reflection of the environment on the cheese and tray (Figure3.19(c)).

iv. **The white porcelain tray,** the cheese has got a better view within cooking levels; since white color is included all spectrums of the light (Figure 3.19(d)).

(a) Pyrex-tray

(b) Black iron-tray

(c) Silver Aluminum-tray

(d) Porcelain-tray

Figure 3.19 Effect of the Tray Type on the Image

Normally, cheese's color is between yellow and orange, and it has a clear effect in its environment.

CHAPTER 4

IMPLEMENTATION OF DIGITAL IMAGE PROCESSING USING MATLAB

4.1 Introduction:

In recent years, digital image processing grow speedily covering a wide range of human activities such as medical, industrial, military, security and electrical applications. Where it be named as the science of improvement digital image processing using all the techniques and applications to analysis the image such as, sharpening, noise removal, deblurring, edge extraction, binarization, blurring, contrast enhancement, object segmentation and labeling. The implemented method for digital image processing is carried out using software, which is relying on the programming languages like LABVIEW, MATLAB, etc. Matrix Laboratory or what amalgam from it is called 'MATLAB'. It is the software that has ability to edit and improve digital image processing techniques. A multiplatform, prototyping, data analysis, speed process, interactive language and rich graphics capability properties lead to be a very popular with scientists, engineers and researchers in both industry and academia fields. However, analysis of an image required sequential processing where the domain of the steps process depended on the scope of the image, and image specifications. Analysis of the image is a main step to construct an important impression about which tools will need to get a perfect result for building suitable algorithm process.

4.2 Basic Steps to Build the Algorithm

Overall, analysis of image helps to construct a concept of what type of problems will be faced and the key of the steps to achieve the goal. These steps are ranging from easy to complex, depending on the image specifications and the aim behind process. The analysis of image is depended on:

- ✐ Plot colormap
- ✐ Indexed image
- ✐ Display histogram of image data
- ✐ Convert Image to Binary Image, Based on Threshold
- ✐ Observe the images for RGB channels separately

The cheddar cheese images will be addressed as a model images to explain the outline of the proposed algorithm in the Section 4.3. Figure 4.1 shows these samples; Cheddar, Kashar, and Mozzarella is as Figure 4.1(a), Figure 4.1(b), and Figure 4.1(c) respectively.

(a) Cheddar

(b) Kashar

(c) Mozzarella

Figure 4.1 Samples of Cheddar, Kashar, and Mozzarella Cheeses

4.2.1 The Plot of Colormap

Typically, color image consist of two matrices: an image and a colormap matrix. Matrix represents the color in the image called ‘colormap’, while image matrix is a matrix which contains a corresponding index into the colormap for each pixel called as ‘indexed image’. A 1-by-3 red, green, and blue (RGB) color vector is the size of the colormap:

$$Color = [R\ G\ B]$$

Colormap represent the intensity amounts of the red, green, and blue colors in the image, which is normalized to a value ranging from 0 (black) to 1 (full intensity).[25]

Through drawing colormap of RGB channels as seen in Figure 4.2. The following points can be concluded:

- Show the colormap distributions along the sample image.
- The progressively of the intensity form highest value (red color) to the lowest value (blue color) as shown in Figure 4.2. The sequence of the arranging channels change depended on the object and background colors.
- The darkness and lightness of the image by observing the high intensity value of the colors values. As an illustration, Figure 4.2(a), Figure 4.2(b), and Figure 4.2(c) show the highest values of cheddar, Kashar, Mozzarella cheeses 0.5333, 0.6157, and 0.6078 consecutively. These values indicate that cheddar is darker than Kashar and Mozzarella, while Kashar is the lighter one comparing with the cheddar and Mozzarella.
- See the effect of process on the range of image colors, if process influence compression, extension or constant by comparing the range of mapping color before and after the process.
- Colors oscillations display an expectations:
  - If the oscillations of the RGB are near from each other and lightly, the object and background have close color. While, if one Channel or more than one have a widely oscillation rather than others, and others are nearly have the same oscillation, than the object and background have different colors.
  - If the Low channel has oscillated extensively, then the object or background is darker than the background or object.

- The channel which has high oscillation than others is the perfect channel for extract the object from the background. While the low oscillation of the channel indicate that channel is not suitable for histogram operation.
- The highest channel shares the huge amount of the illumination of the whole image as appears in the example (red channel)

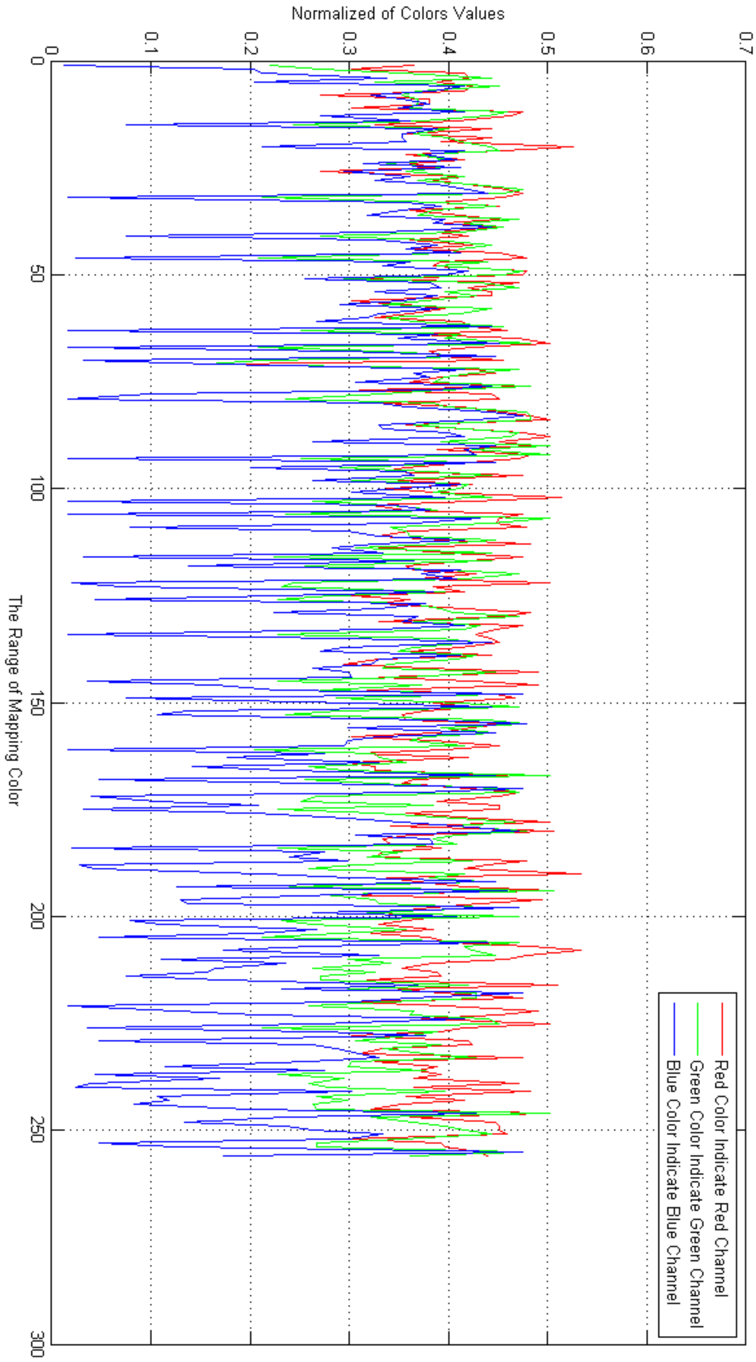


Figure 4.2(a)

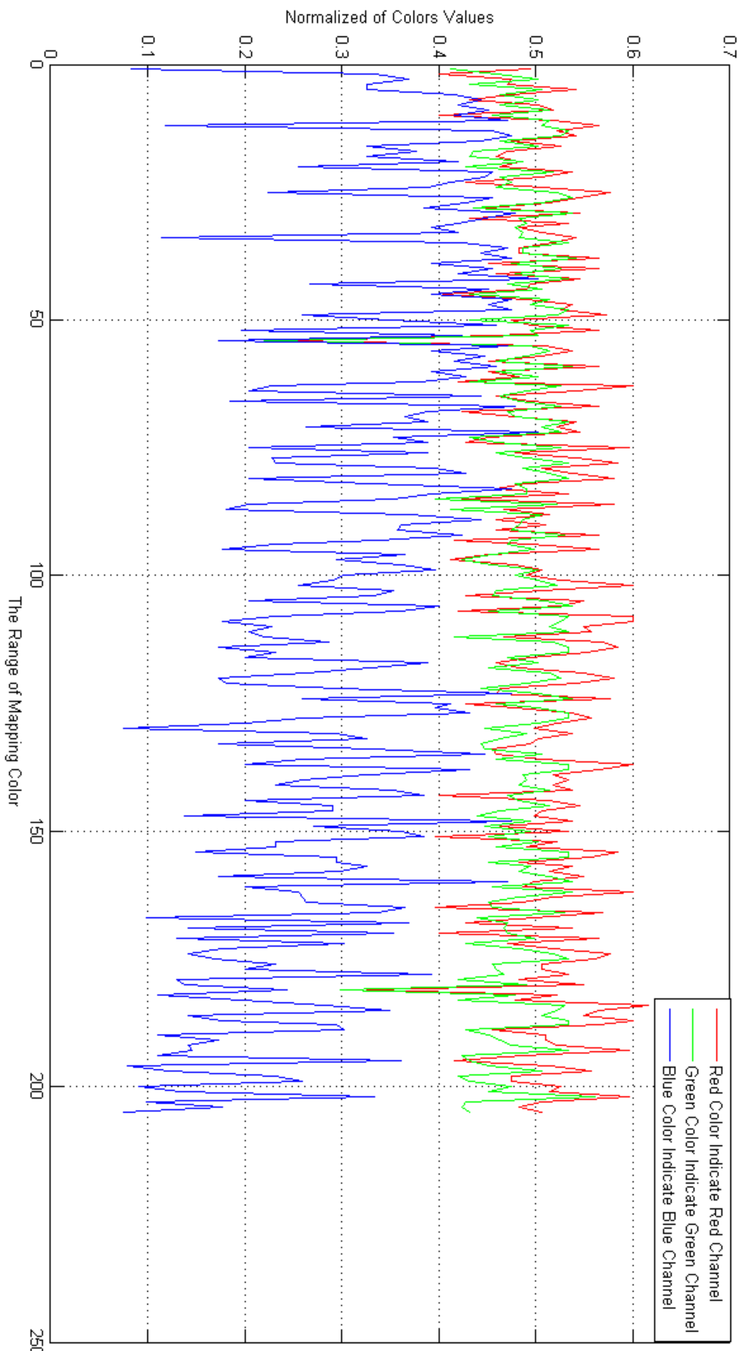

Normalized of Colors Values
The Range of Mapping Color
Red Color Indicate Red Channel
Green Color Indicate Green Channel
Blue Color Indicate Blue Channel

Figure 4.2(b)

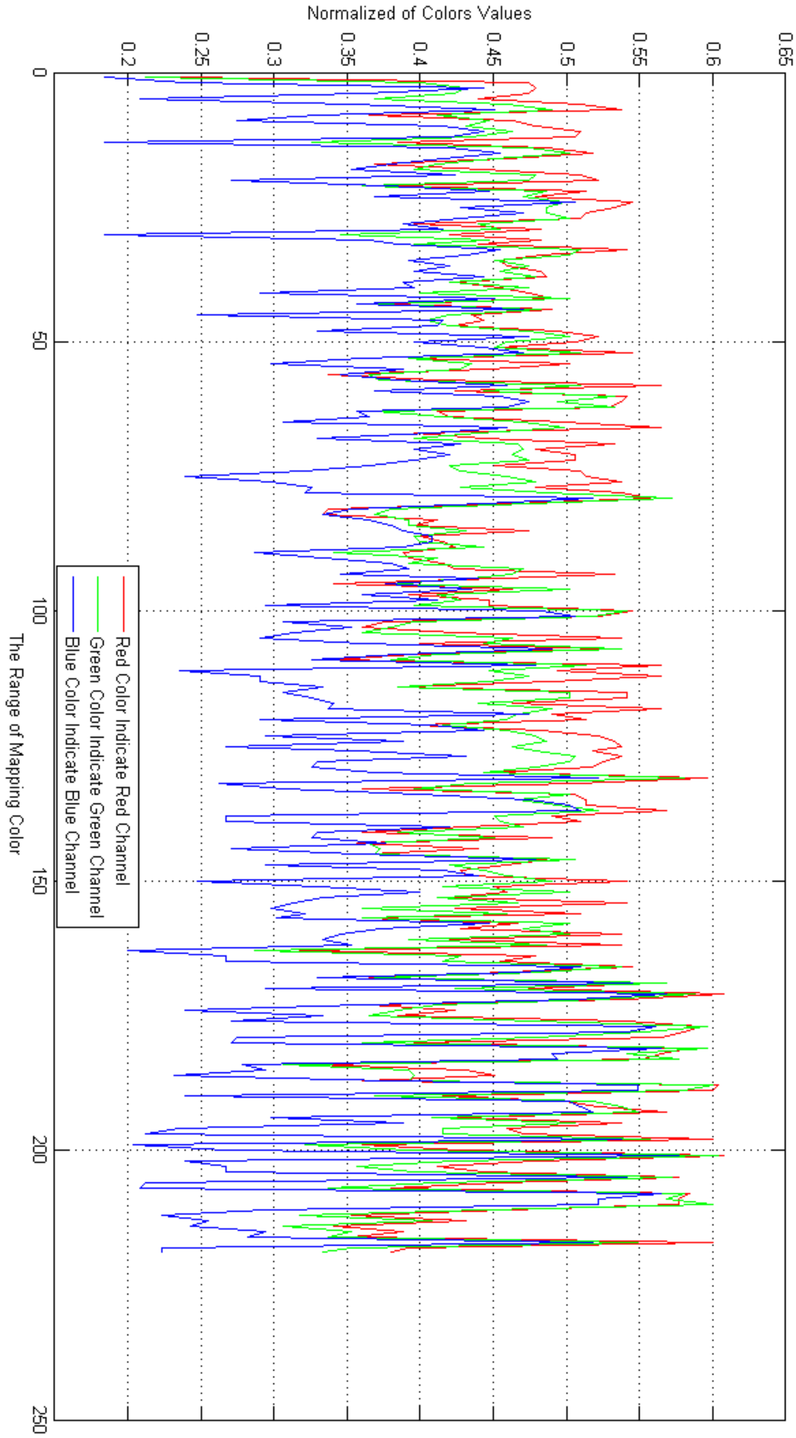


Figure 4.2(c)

Figure 4.2 (a) Plots of Red, Green, and Blue Colormap of (a) the Cheddar Cheese, (b) the Kashar Cheese, and (c) the Mozzarella Cheese

4.2.2 Indexed of the image

As mentioned in Section 4.2.1, the intensity of the red, green, and blue components of color (RGB) are real scalars that range from 0 (black) to 1 (full intensity). When an image and its colormap are displayed, these values are translated using MATLAB into display intensities. MATLAB displays an indexed image using the values of the image matrix to find the desired color in the colormap. As an illustration, if the value 3 in the image matrix located at (2, 4), then the color for pixel (2, 4) is the color from row 3 of the colormap as seen in the Figure 4.3. It is almost like labeling every color by number in the memory. [25]

Indexed color is one important technique used to speed up file transfer, and display, save computer memory, and file storage.

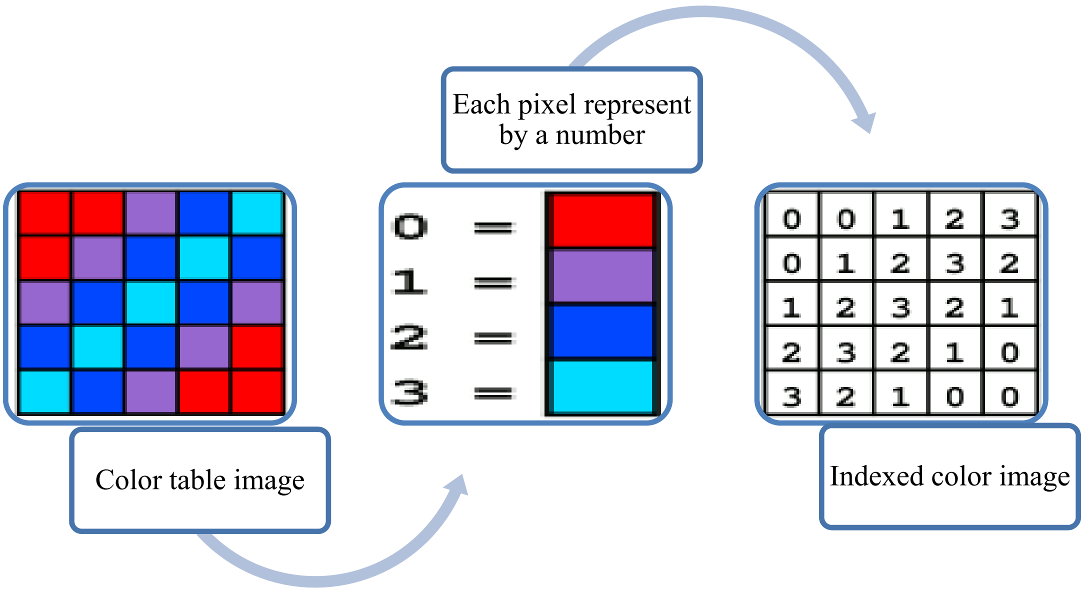


Figure 4.3 The Structure of an Indexed Concept

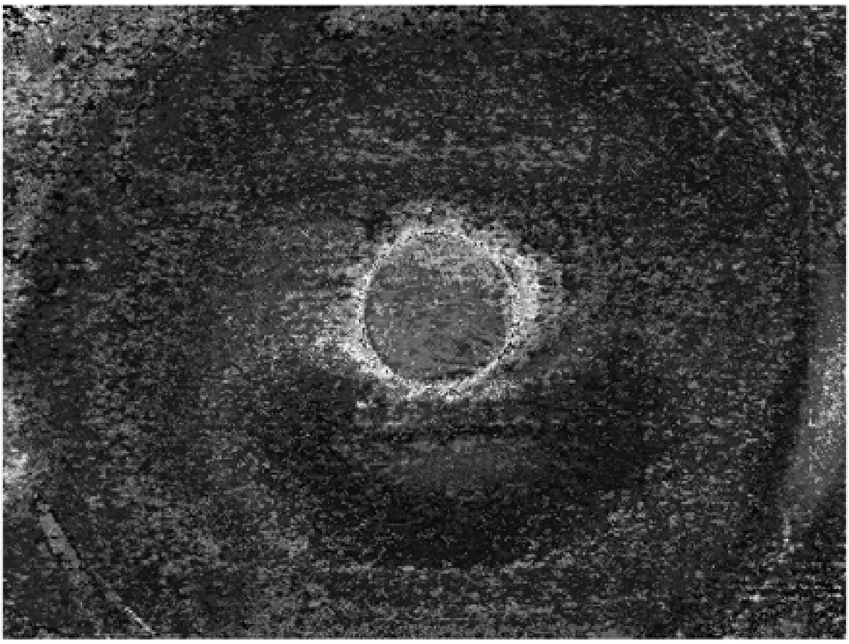
Indexed image can give an impression about:

- The smoothing of the image, style of spreading color, light reflection, and shadow. Theoretically, the indexed image of Figure 4.4(a) has to consist of two numbers, one represent white color (dish), the others represent orange (cheese color). Since the noise, light reflection, and shadow can effect the colors of the image, Figure 4.4(b) indicates the result incompatibly with what expected lastly.

To summarize, indexed image reversed the environment of the image where it has been taken.

- It can give a thought about the effect of the filter to decrease or increase the noise in each step by comparing the decrease or increase acting numbers before and after the image process and observing the indexed image.

(a) Original Image



(b) Indexed Image

Figure 4.4 Indexed and Original Images of the Specimen

4.2.3 Display Histogram of Image Data

An image histogram is a graphical representation showing a visual impression of the distribution of intensities in an image, as show in Figure 4.5. It consists from two or more than two dominant modes representing the objects and the background of the image as shown in Figure 4.5(a).

In Figure 4.5, it is observed that the histograms of image data were agree with the result of the previous Section 4.2.1. Also, comparing the red (Figure 4.5(b)), green (Figure 4.5(b)), and blue (Figure 4.5(c)) histogram, reveal that the amounts of noise decrease gradually from red, green, and blue channels successively. Besides, the information in a histogram gives an impression to select a suitable enhancement operation. For instants, if the range of intensity values is small in an image histogram, than adjustment technique is the appropriate function to spread the values across a wider range as shown in Figure 2.8.

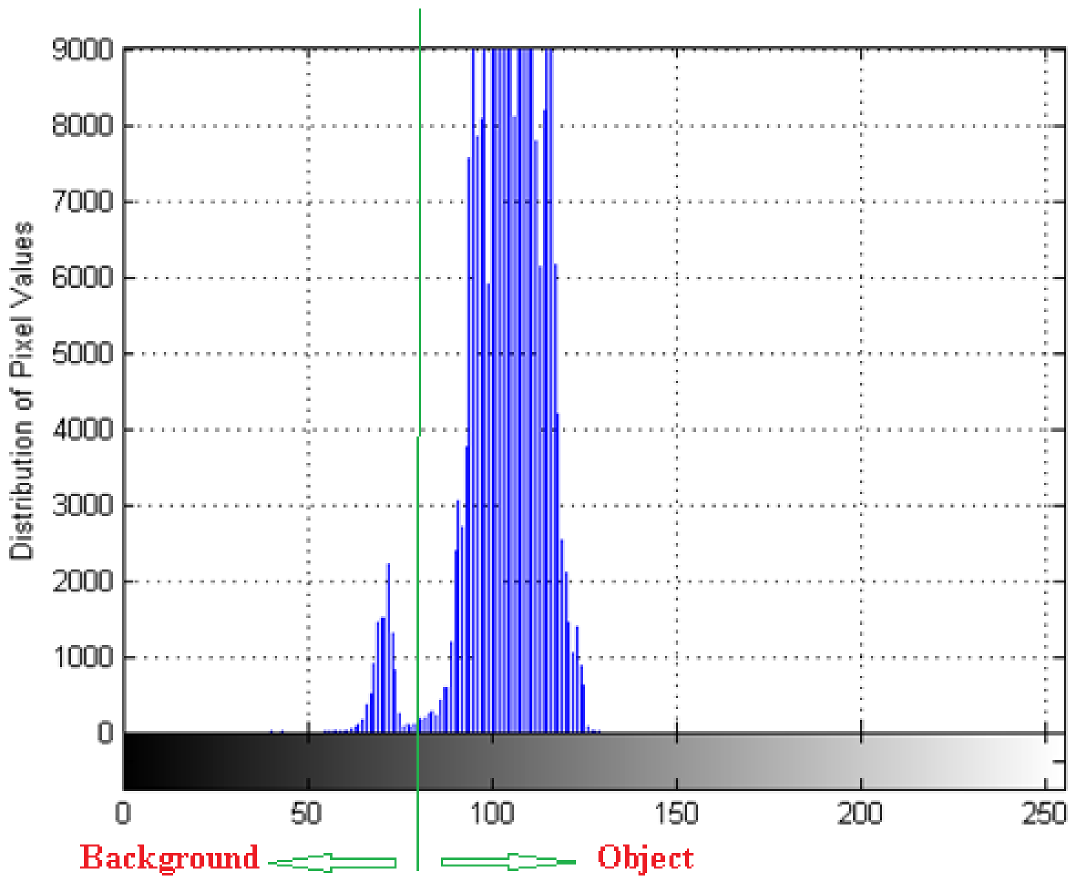


Figure 4.5 (a)

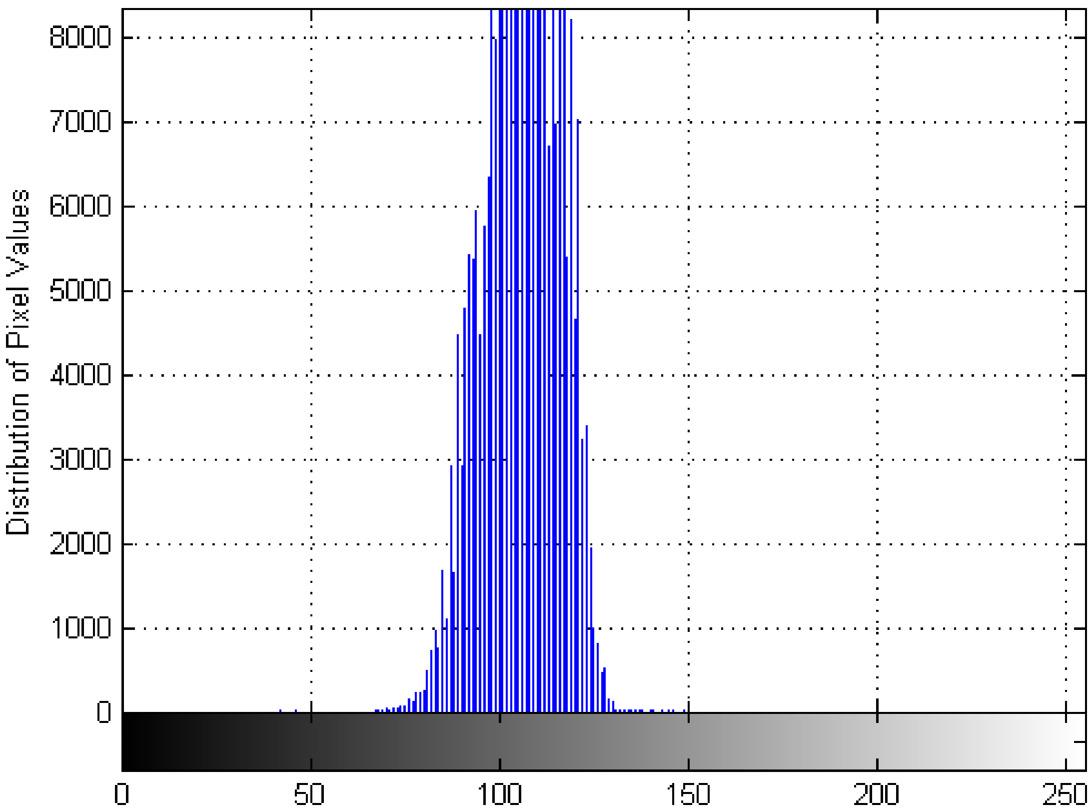


Figure 4.5 (b)

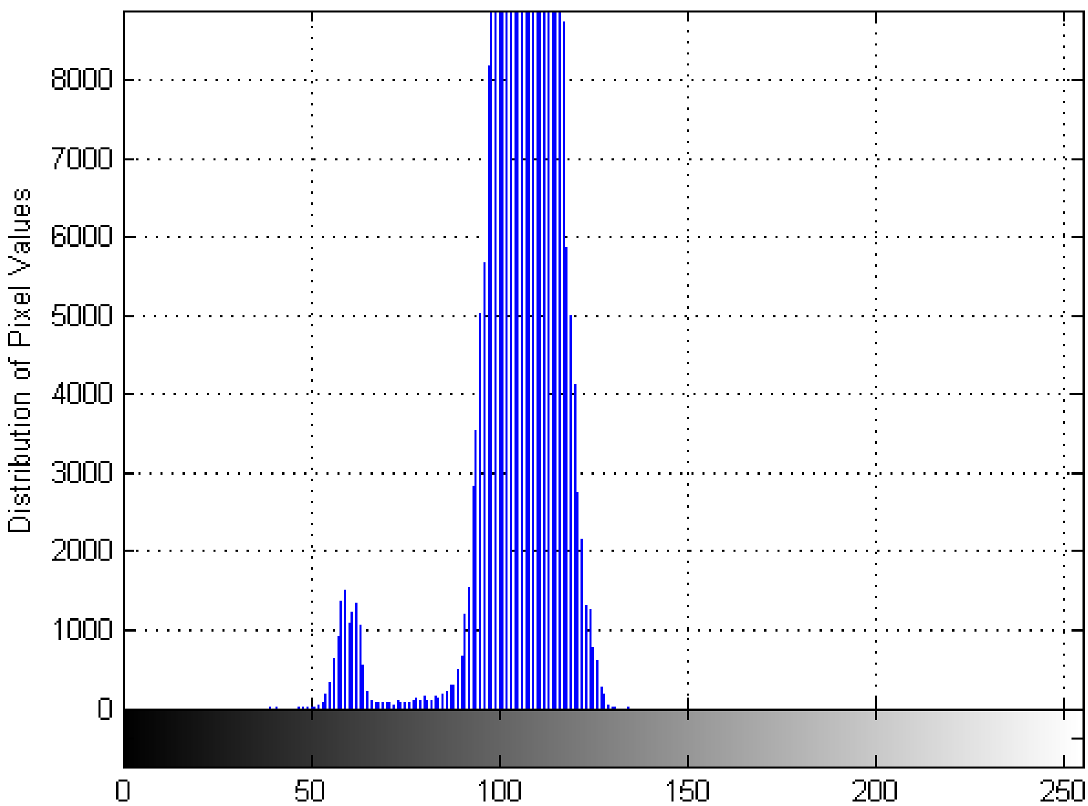


Figure 4.5 (c)

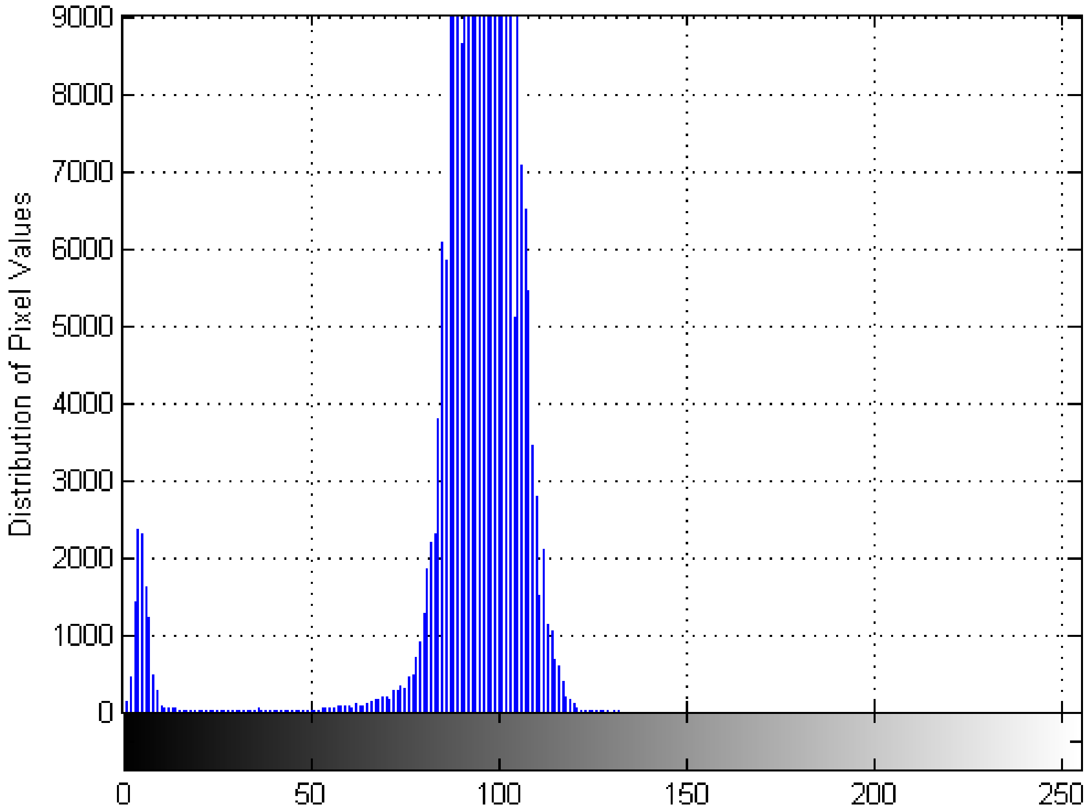


Figure 4.5 (d)

Figure 4.5 Histogram of images; (a) Gray image, (b) Red image, (c) Green image, and (d) Blue Image. X-axis Indicate the Image Type

4.2.4 Convert Image to Binary Image, Based on Threshold

A binary image is a digital image stored as a logical array of pixels, where each pixel has only two discrete values: 1 or 0. Global image thresholding is the way to convert an intensity image to a binary image by computing the level argument using Otsu's method.

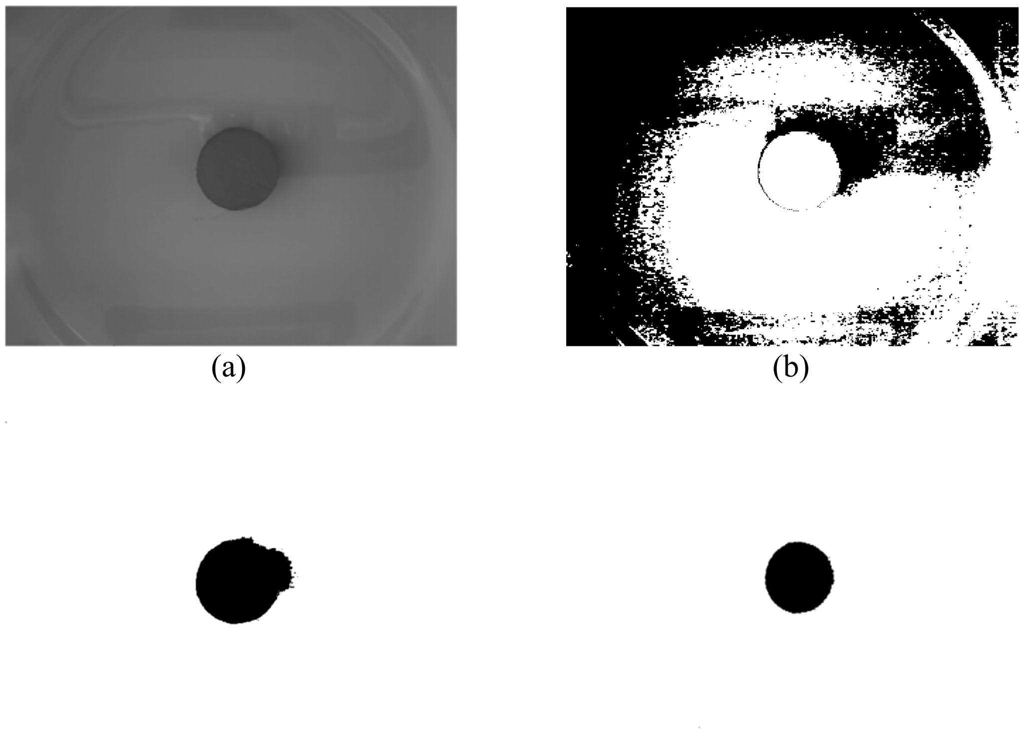
Thresholding value is partitioning image into two dominant modes, in such a way that one dominant represent the object greater than thresholding value, and the lesser than thresholding value represent the background as shown in Figure 4.5(a). Table 4.1, shows the thresholding values which is a valley value between object and background intensity. From Table 4.1, the values which are suitable to extract the object from background in every case computed using Otsu's method. However, level of noise has been seen in every case speared from highest to the lowest, red channel, gray level, green channel, and blue channel at the border values as shown in Figure 4.5.

Table 4.1 Thresholding Values of Color, Gray, Red, Green, and Blue Images

Types	Color	Gray	Red	Green	Blue
Thresholding values	0.2267	0.4	0.4118	0.3294	0.2
Thresholding values (uint8)	68	102	105	84	51

To observe capability of these values for dividing the image into two parts, background and object, and build a concept about what is the noise effect on the image, let turn them to binary images.

Simply, Figure 4.6 improves the vague supposition of noise existence and the ability to extract the object in blue channel easier and less noisy than others. Also, results are agreed with the Table 3.5, where the object color near from red rather than green and blue color. Because of that, can be seen the blue value thresholding is the best value for extracting object.



(a) (b) (c) (d)

Figure 4.6 (a) Original Gray Image, (b) Red Thresholding Value, 105, is Applied onto Red Image, (c) Green Thresholding Value, 84, is Applied onto Green Image, and (d) Blue Thresholding Value, 51, is Applied onto Blue Image.

To clear the view of the noise influence, Figure 4.7 is transformed the gray image to a binary image by each channel's value. It is clear from gray histogram (Figure 4.5(a)), that blue thresholding value 53 have a less effect on the gray image and the red thresholding value 105 shows the highest influence. While, green thresholding value 84 try to keep it impact. These results in Figure 4.7 show red intensity has a large share of the total illumination.

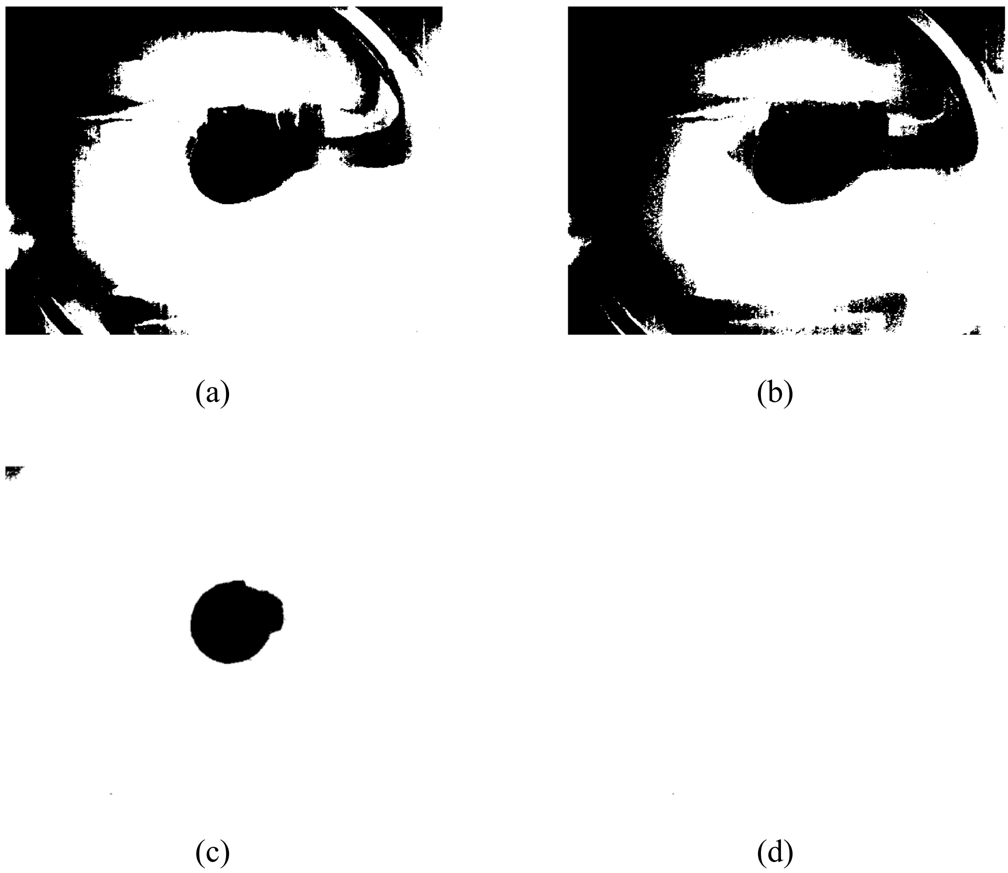
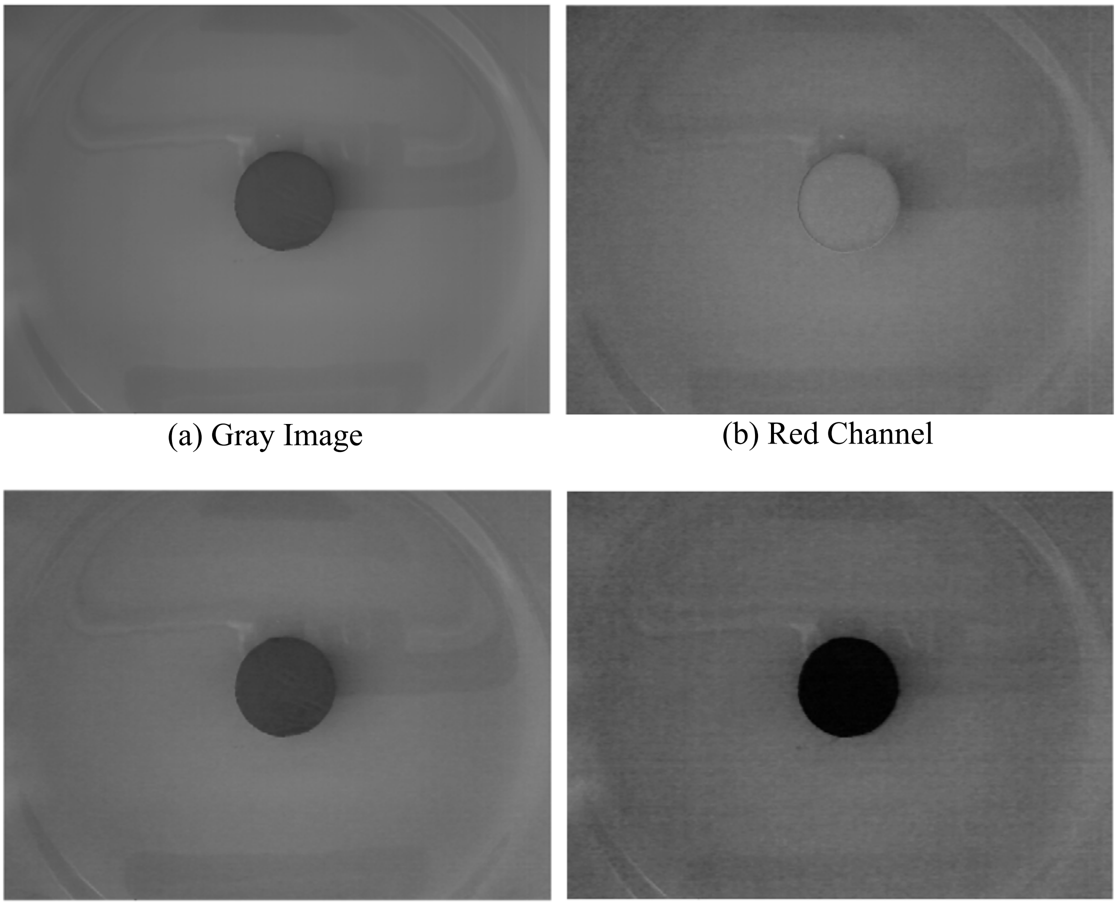


Figure 4.7 (a) Gray Image Thresholding Value, 102, is Applied onto Gray Image (b) Red Thresholding Value, 105, is Applied onto Gray Image, (c) Green Thresholding Value, 84, is Applied onto Gray Image, and (d) Blue Thresholding Value, 51, is Applied onto Gray Image.

4.2.5 Observe the Images for Red, Green, and Blue Channels

In Figure 4.8, Gray, Red, Green, and Blue images clarify the idea about what has been explained in Sections 4.2.1, 4.2.2, 4.2.3, and 4.2.4. Starting with the red channel, the object appeared to be close to the background color and noisier rather than the other channels. Followed by both images green and blue, it is clearly seen that both objects have a dark color in comparison with the previous one.

Each channel has a certain value of intensity of the image, where, the red color has a huge portion of image intensity. While the green and blue channels have less intensity respectively in comparison with the red ones.



(a) Gray Image (b) Red Channel

(c) Green Channel (d) Blue Channel

Figure 4.8 Noise, Shadow, and Reflection of the Images; (a) Gray level, (b) Red Channel, (c) Green Channel, and (d) Blue Channel

4.3 The Proposed Algorithm

As mentioned before, noise, shadow and reflection of the light make difficult extracting object from background. However, building an algorithm procedure to remove these effect and getting the scope, have been approved by these steps:

- ✐ Image contrast enhancement by logarithmic transformation
- ✐ Image sharpening enhancement
- ✐ Image contrast enhancement (Lab color space method)
- ✐ Filtering and sharpening R, G, and B channels separately
- ✐ Segmentation color image
- ✐ Calibration image
- ✐ Morphology operations and calculating area

4.3.1 Image Contrast Enhancement by Logarithmic Transformation

Improving the intensity of the image is an essential step of preparing process. Many methods can enhance the image, but almost of these methods work on the gray images which cannot apply to the color images. Besides, applying one of these methods to enhance the RGB channels separately increase the noise in each channel, which will be construct a noisy image. However, some color enhancement methods provide acceptable result. Since having an image with different levels of intensity and noise in each channel as shown in Section 4.2, drive towards finding a method accomplish the spreading of the intensity image into a wider range of output levels and decrease the noise in the image.

Logarithmic transformation is one of the intensity transformation technique which improving the quality of an image by operates on single pixels, in the way that the result will be more suitable for specific application and visual inspection.

Logarithmic transformation method is the basic tool for dynamic range manipulation as shown in Figure 4.9. It is given by the expression

Where c is constant (scale factor), and it is assumed that input intensity level >= 0.

It has ability to expand the values of dark pixels and compression the higher level values of the intensity as shown in Figure 4.10.

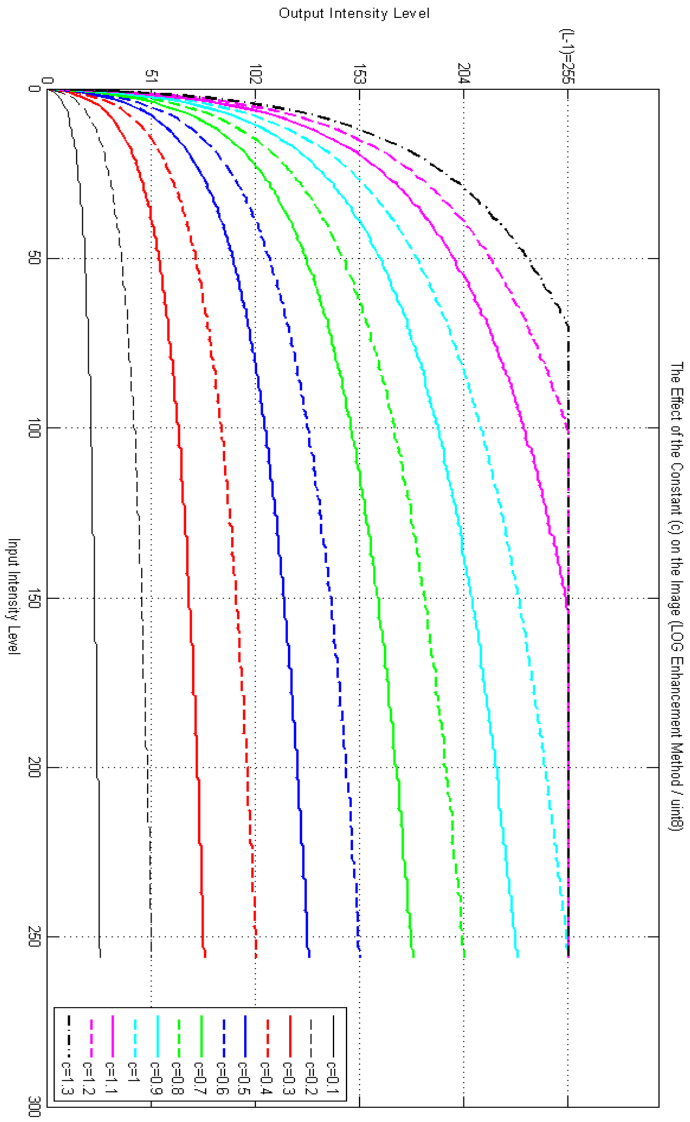
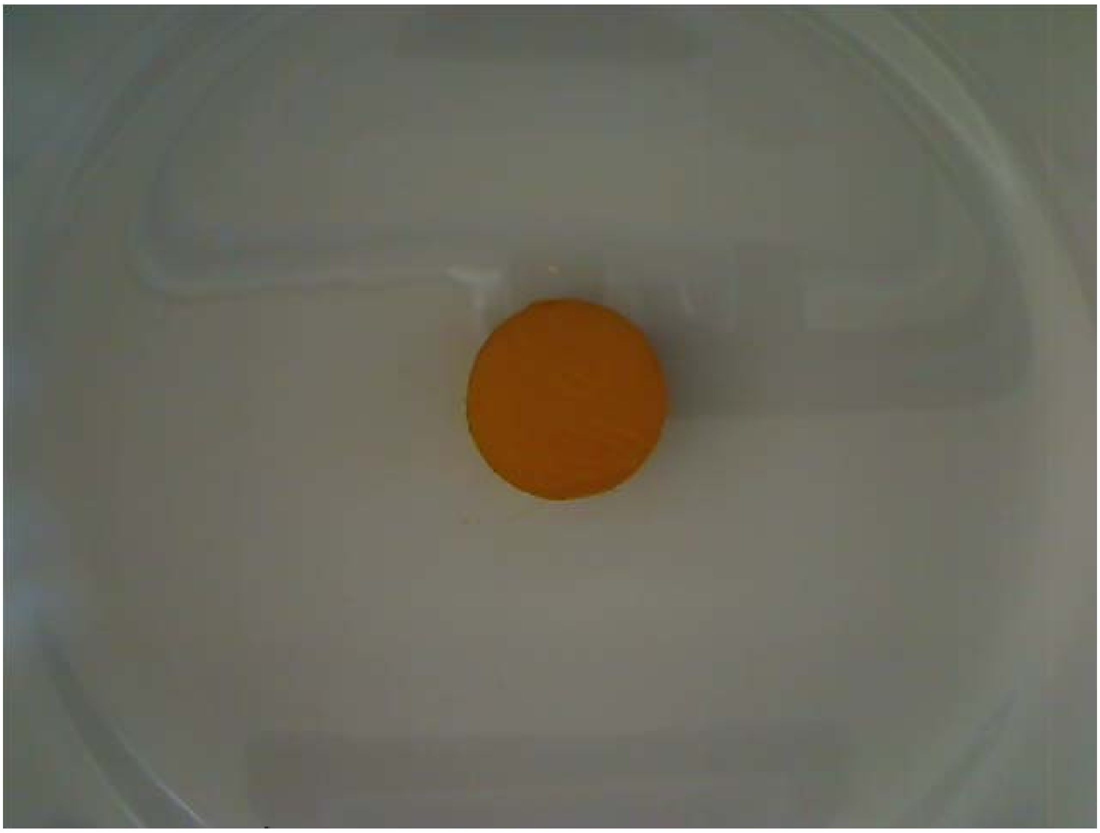


Figure 4.9 Logarithmic Intensity Transformation Function. Where (L-1) is the Maximum Intensity Level of an Image.



(a)

(b)

Figure 4.10 (a) Before Logarithmic Process, and (b) After Logarithmic Process

Figure 4.11 show the colormap distributions along the image process before (Figure 4.11(a)) and after (Figure 4.11(b)) logarithmic process. Observing the high intensity value of the red before (0.533) and after (0.89) log process clear the effect of the log technique, where it became lighter. Furthermore, it shows the expanding and spreading of the colors along the image by comparing the range values of the RGB channels before (red= [0.19, 0.53], green= [0.2, 0.5], blue= [0.01, 0.47]) and after (red= [0.68, 0.89], green= [0.88, 0.67], blue= [0, 0.87]) log process. Moreover, it is shows the compression effect of the higher level values of the higher intensity by comparing the values before (red (0.53-0.91=0.34), green (0.5-0.2=0.3)), and after (red (0.89-0.68=0.21), green (0.88-0.67=0.21)) log process. The oscillation of the colors refer that the object and background colors are close to each other in the red, and green channel rather than the blue channel which has a huge oscillation.

The degree of smoothing shows in the indexed image is clear the log effect on the image noise as shown in Figure 4.12. It is display that the log reduced the image noise by increasing the image intensity as seen in Table 4.2. As it seen from this table thresholding values are increased for all types of color (RGB), gray level, red channel, green channel, and blue channel images.

Figure 4.13 and Figure 4.14 display histogram of images data; gray level, red channel, green channel, and blue channel before and after log process. It shows that the band became smaller and less noisy at the thresholding values.

Finally, Figure 4.15 shows the gray, red, green, and blue images. As a result, log process decreases the colors band width, lighting image which work to decrease the noise, shadow and light-reflection, and smoothing image. Besides, it appears the object more clearly than first time.

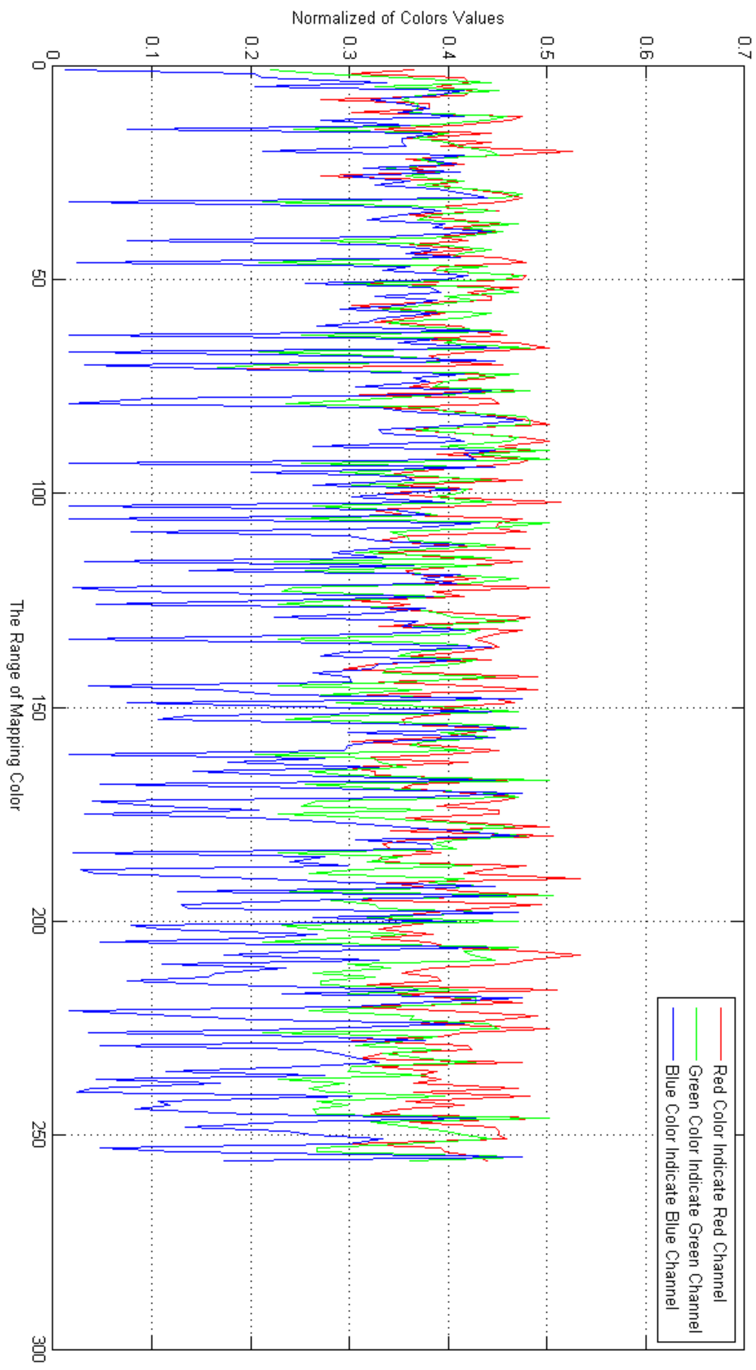

Normalized of Colors Values
The Range of Mapping Color
Red Color Indicate Red Channel
Green Color Indicate Green Channel
Blue Color Indicate Blue Channel

Figure 4.11(a)

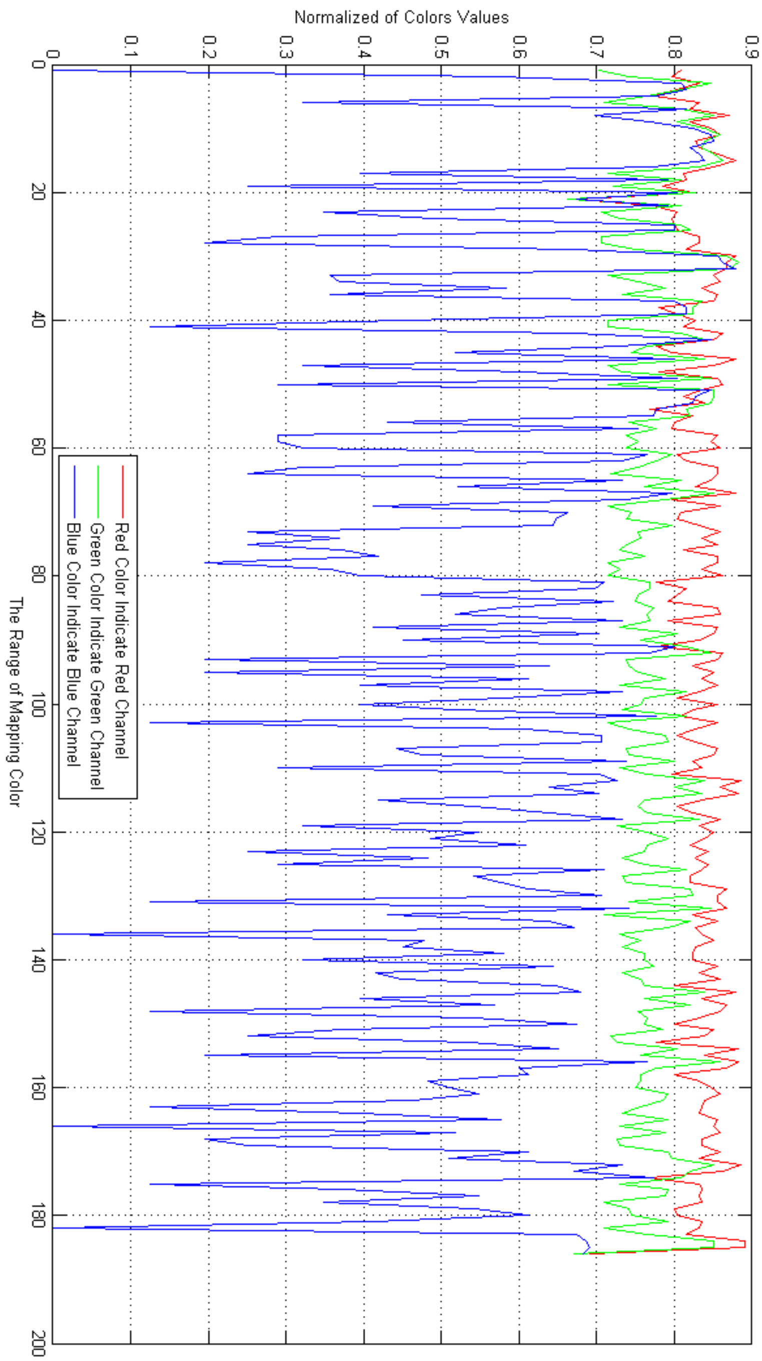
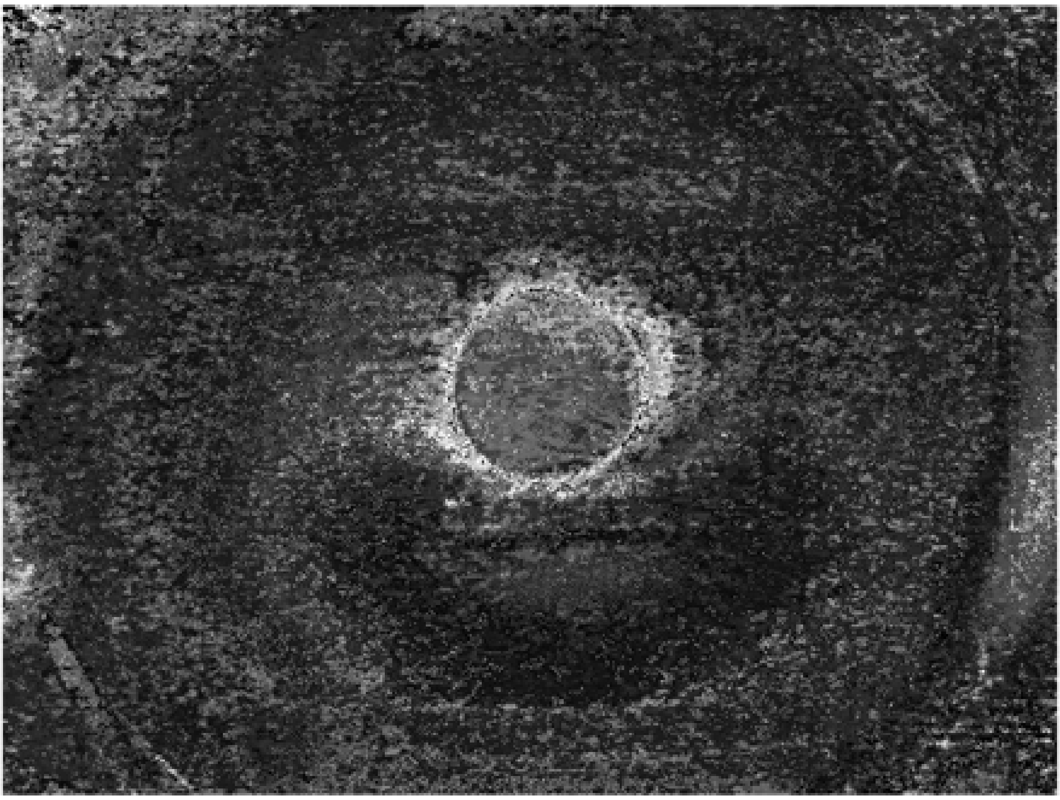
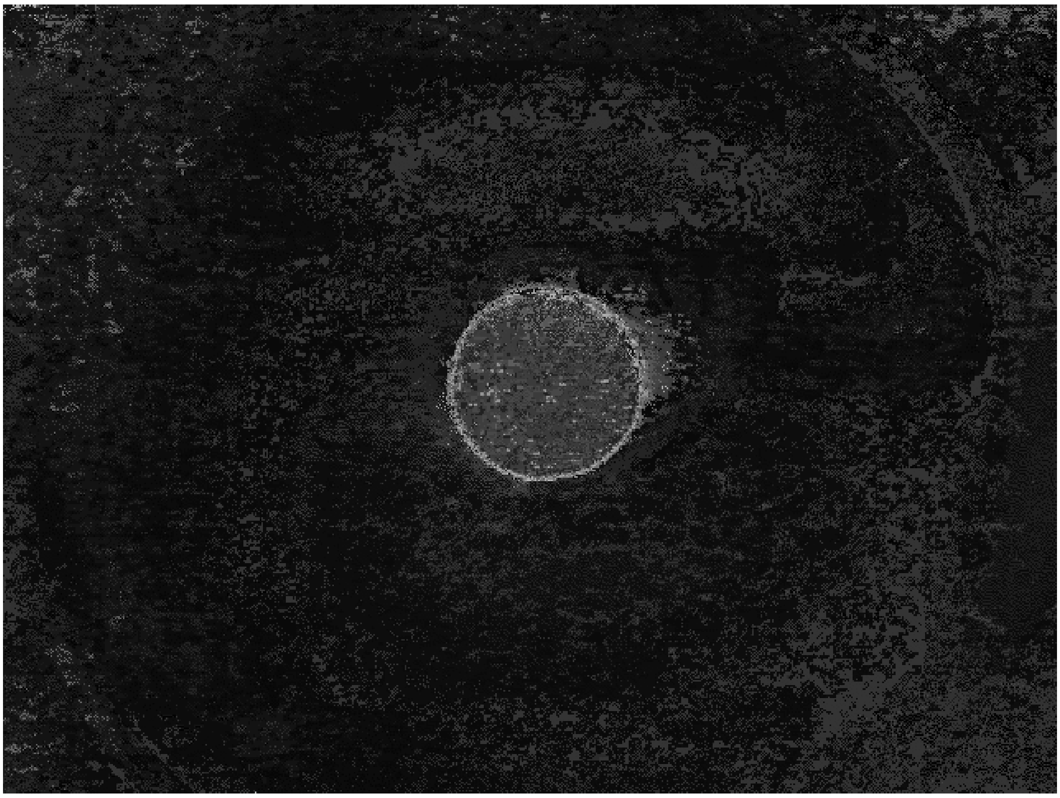


Figure 4.11(b)

Figure 4.11 Plots of Red, Green, and Blue Colormap of the Specimen (a) before, and (b) after Logarithmic Enhancement Process.



(a)



(b)

Figure 4.12 Indexed Image of the Sample (a) before and (b) after Logarithmic Enhancement Process

Table 4.2 Thresholding Values before and after LOG Enhancement Process

Types	RGB	Gray	Red	Green	Blue
Thresholding (Before)	0.2267	0.4	0.4118	0.3294	0.2
Thresholding (uint8/Before)	68	102	105	84	51
Thresholding (After)	0.5745	0.7804	0.8353	0.7882	0.5667
Thresholding (uint8/After)	146.5	199	213	201	144.5

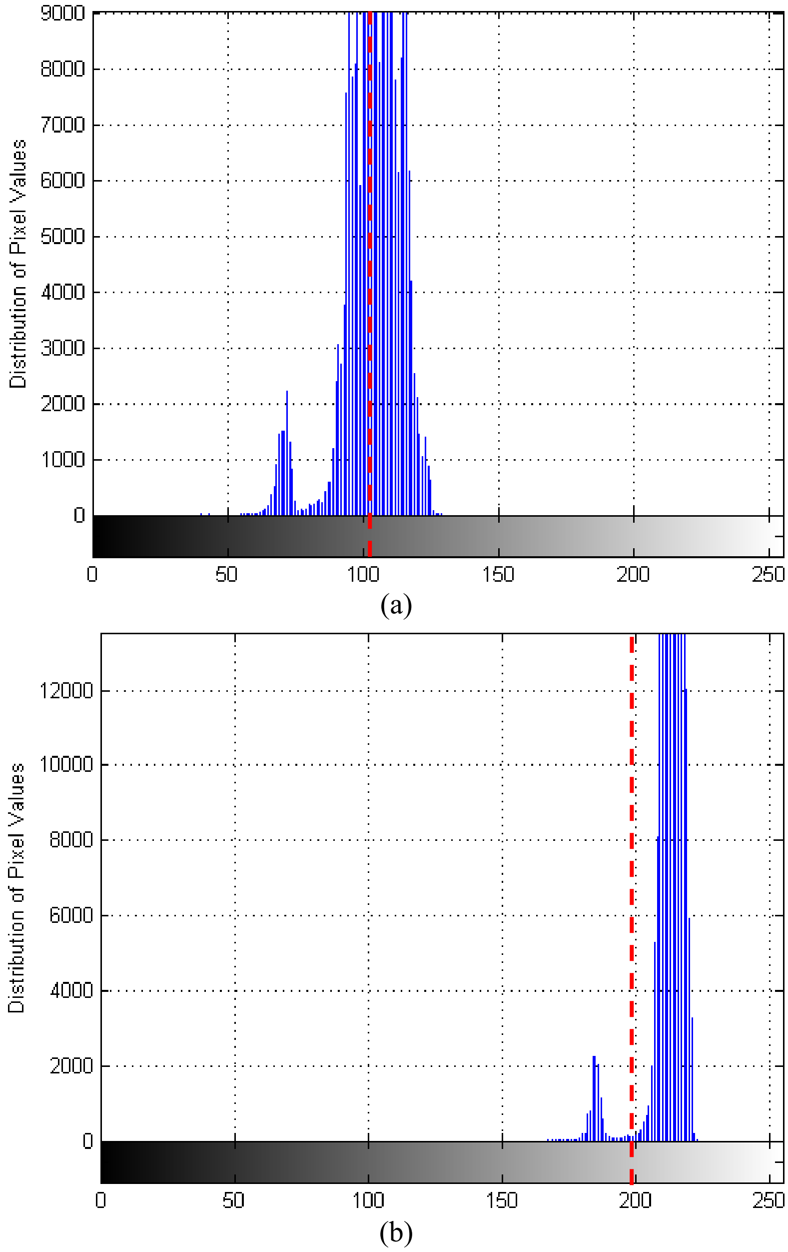


Figure 4.13 The Histogram of Gray Image Data (a) before and (b) after Logarithmic Enhancement Technique; X-axis Indicate the Image Type

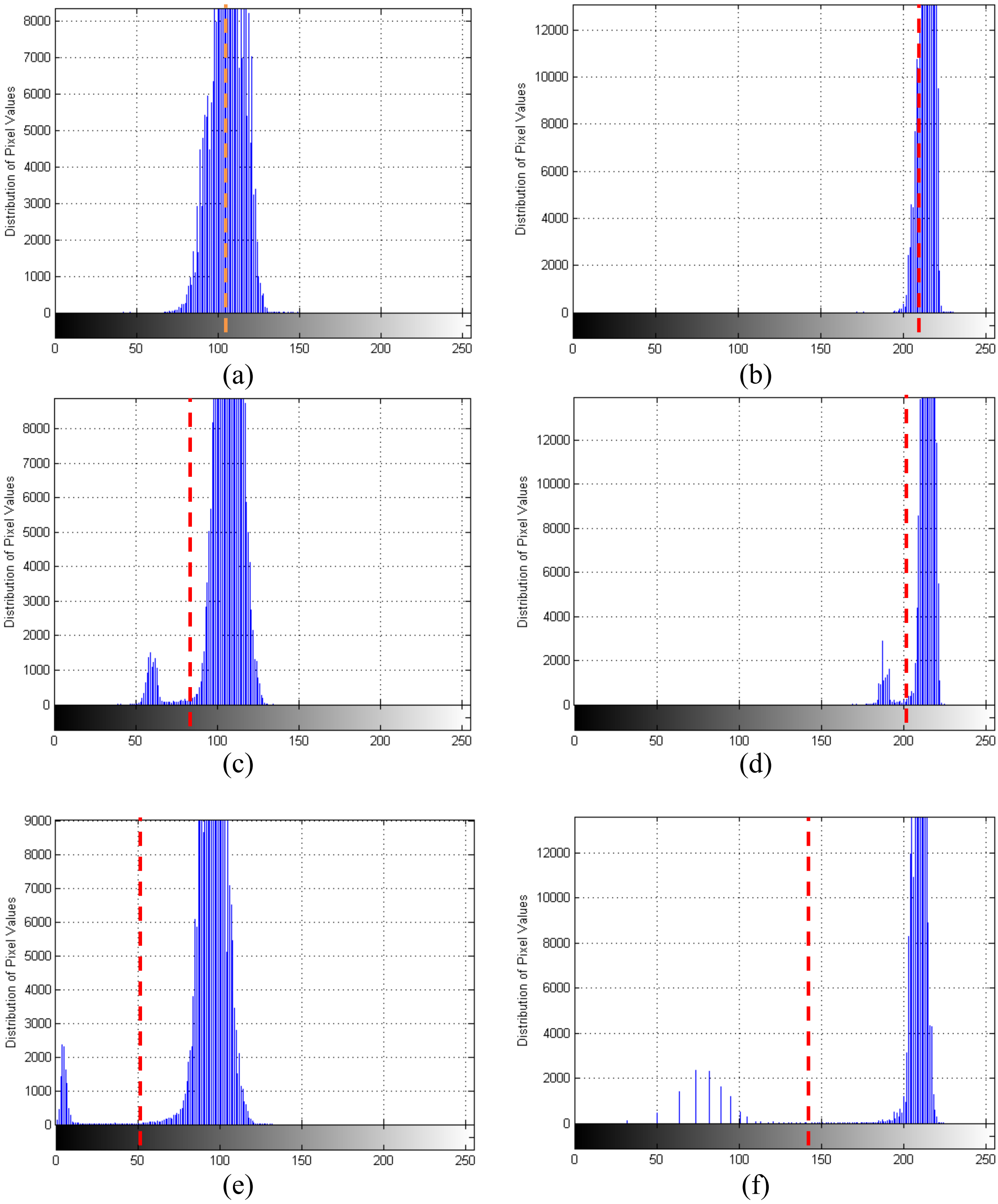
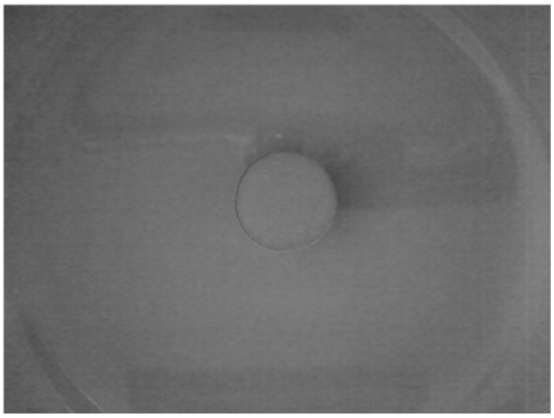
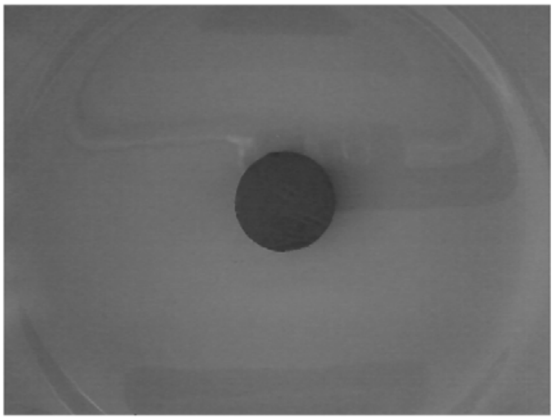


Figure 4.14 The Histograms of Red, Green, and Blue Images Data before and after Logarithmic Enhancement Technique; X-axis Indicate the Image Type. (a), and (b) Histogram of Red Channel, (c), and (d) Histogram of Green Channel, and (e), and (f) Histogram of Blue Channel.



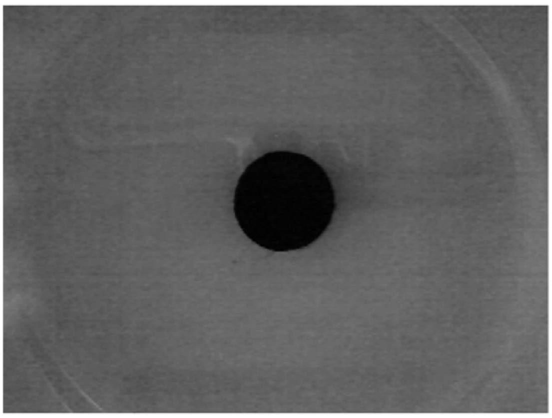
(a)

(b)

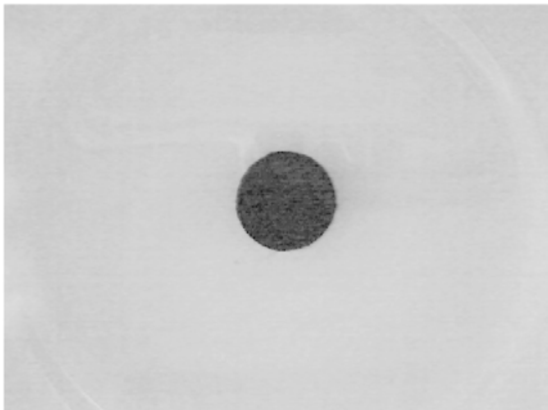


(c)

(d)



(e)



(f)

Figure 4.15 The Images of Red, Green, and Blue Channels before and after Logarithmic Enhancement Technique. (a), and (b) Image of Red Channel, (c), and (d) Image of Green Channel, and (e), and (f) Image of Blue Channel.

4.3.2 Image Sharpening Enhancement

To emphasize some features and/or remove other features, sharpening a color image can be achieved by using linear spatial filters technique like Averaging, Laplacian, Laplacian of Gaussian, and Gaussian low-pass filters.

By using logarithmic process in the previous step (Section 4.3.1) blurred the image is obtained as shown in Figure 4.16(a). This blurring result can be processed by applying Laplacian of Gaussian or what called 'LOG' has a positive action to smooth, and sharpening the image as shown in Figure 4.16(b).

Figure 4.17 display the colormap distribution along the image. It shows that the highest value of the image intensity increased (high intensity = 0.9176). Besides, the amplitude of the oscillation for each channel increased and interacted with each other. Figure 4.18 indexed images reveal the effect of sharpening process clearly, where the edge improved and the object features became clear.

Table 4.3 show the sharpening effect is only a slight changes (-0.5) in color and blue thresholding values. Figure 4.19 and Figure 4.20 show that the band are extended and compressed in all channels. Figure 2.21 shows the images of red, green, and blue channels, where the edge of the object and image shown clearly.


(a)


(b)

Figure 4.16 Sample of Images (a) before, and (b) after sharpening process

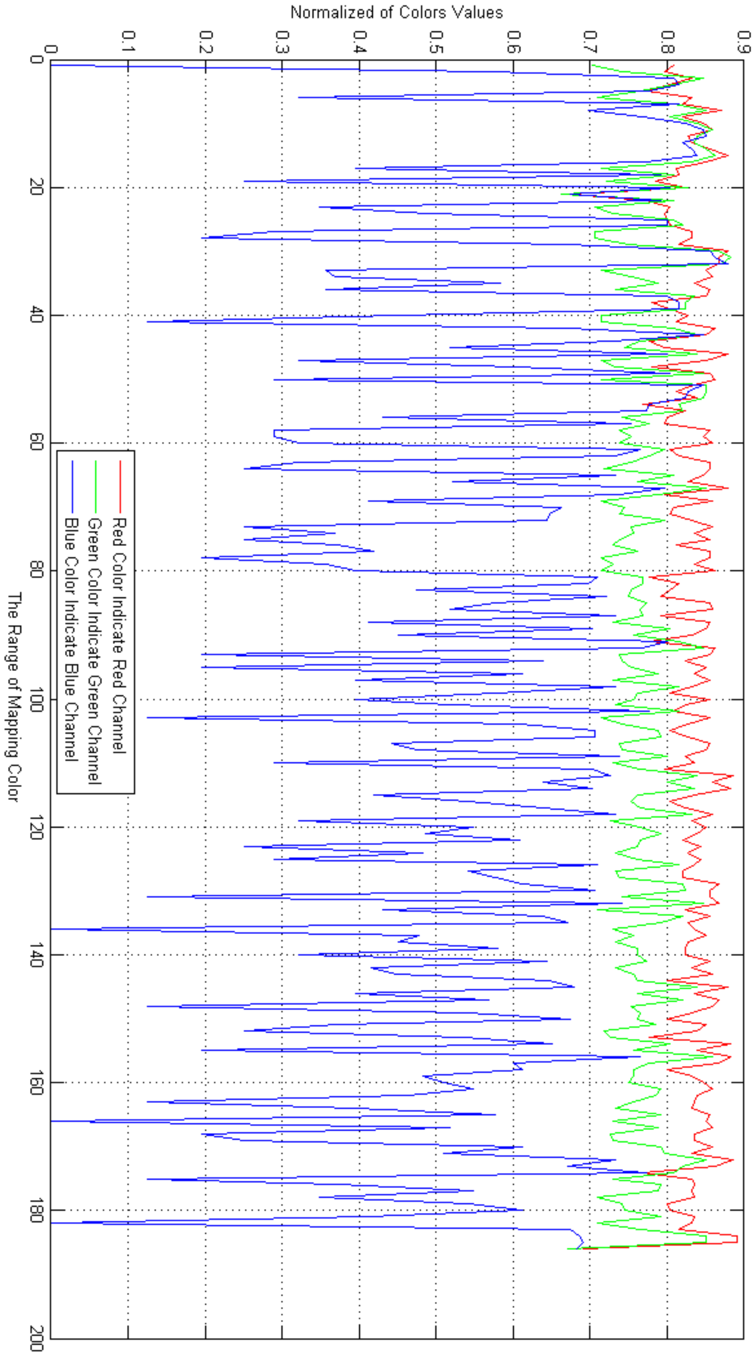

Normalized of Colors Values
The Range of Mapping Color
Red Color Indicate Red Channel
Green Color Indicate Green Channel
Blue Color Indicate Blue Channel

Figure 4.17(a)

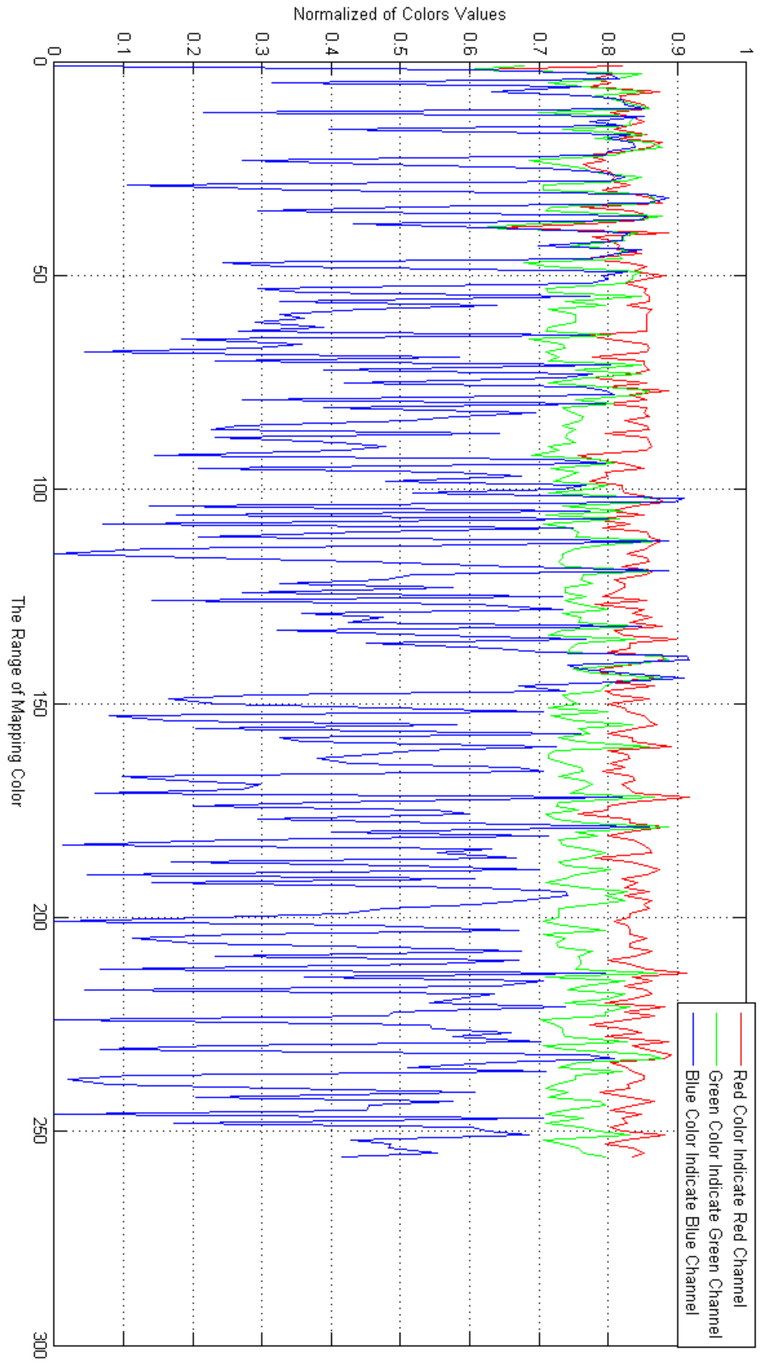
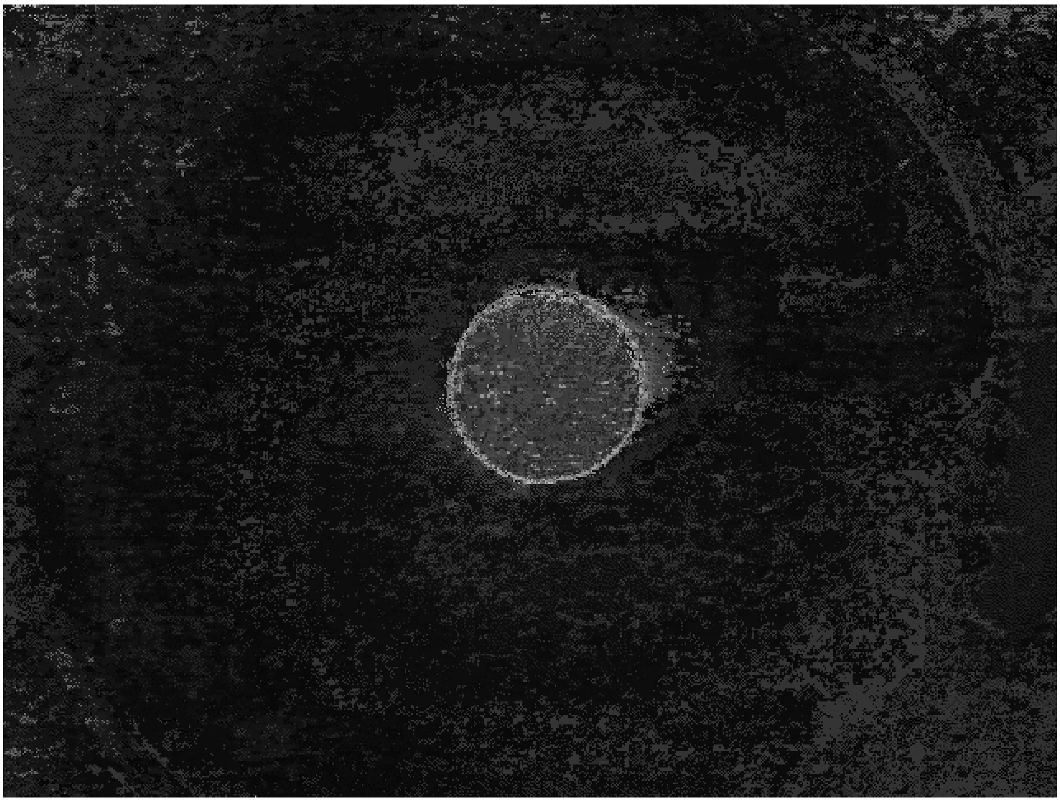
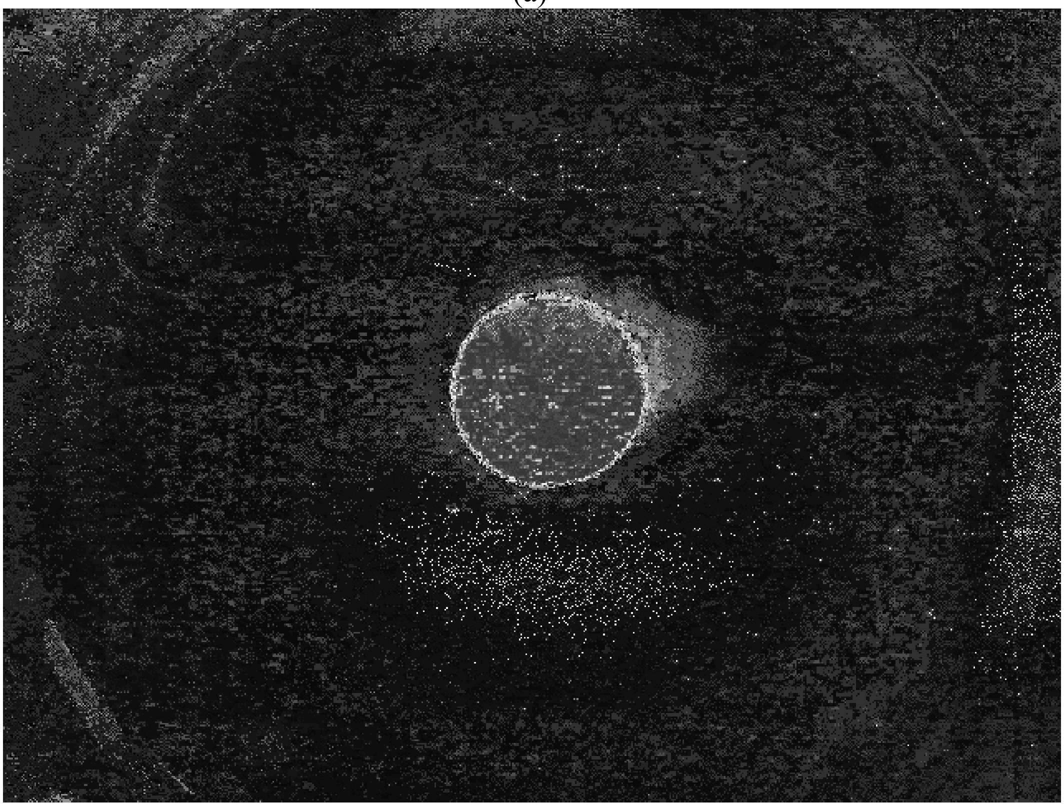


Figure 4.17(b)

Figure 4.17 Plots of Red, Green, and Blue Colormap (a) before and (b) after Sharpening Process.



(a)

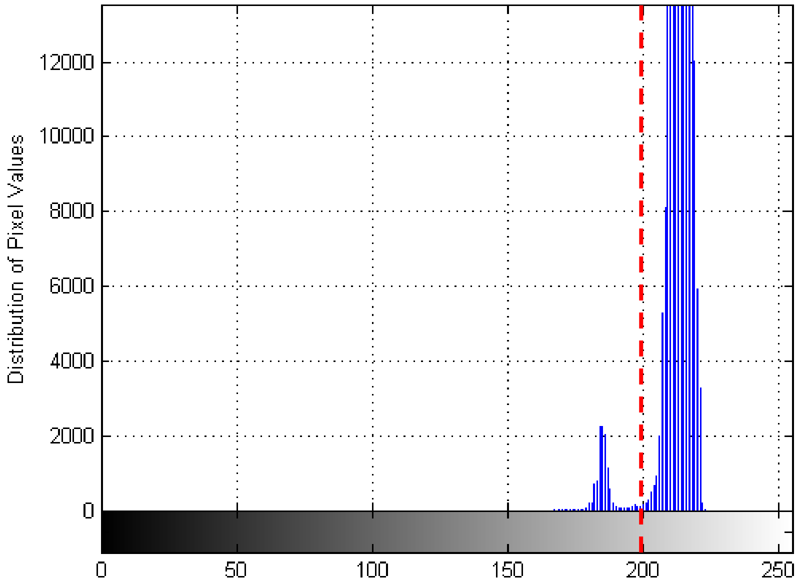


(b)

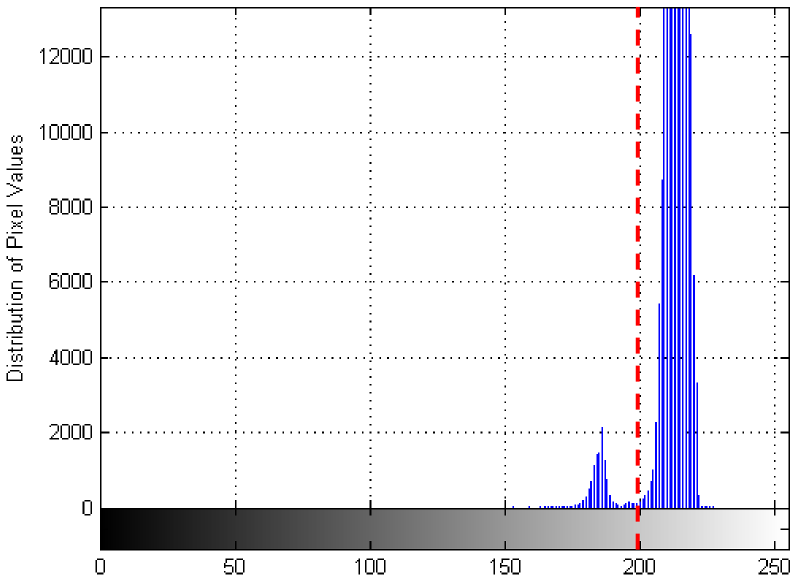
Figure 4.18 Indexed Image of the Sample (a) before and (b) after Sharpening Process

Table 4.3 Thresholding Values before and after Sharpening Process

Types	RGB	Gray	Red	Green	Blue
Thresholding (Before)	0.5745	0.7804	0.8353	0.7882	0.5667
Thresholding (uint8 / Before)	146.5	199	213	201	144.5
Thresholding (After)	0.5725	0.7804	0.8353	0.7882	0.564
Thresholding (uint8 / After)	146	199	213	201	144



(a)



(b)

Figure 4.19 The Histogram of Gray Image Data (a) Before and (b) After Logarithmic Enhancement Technique; X-axis Indicate the Image Type

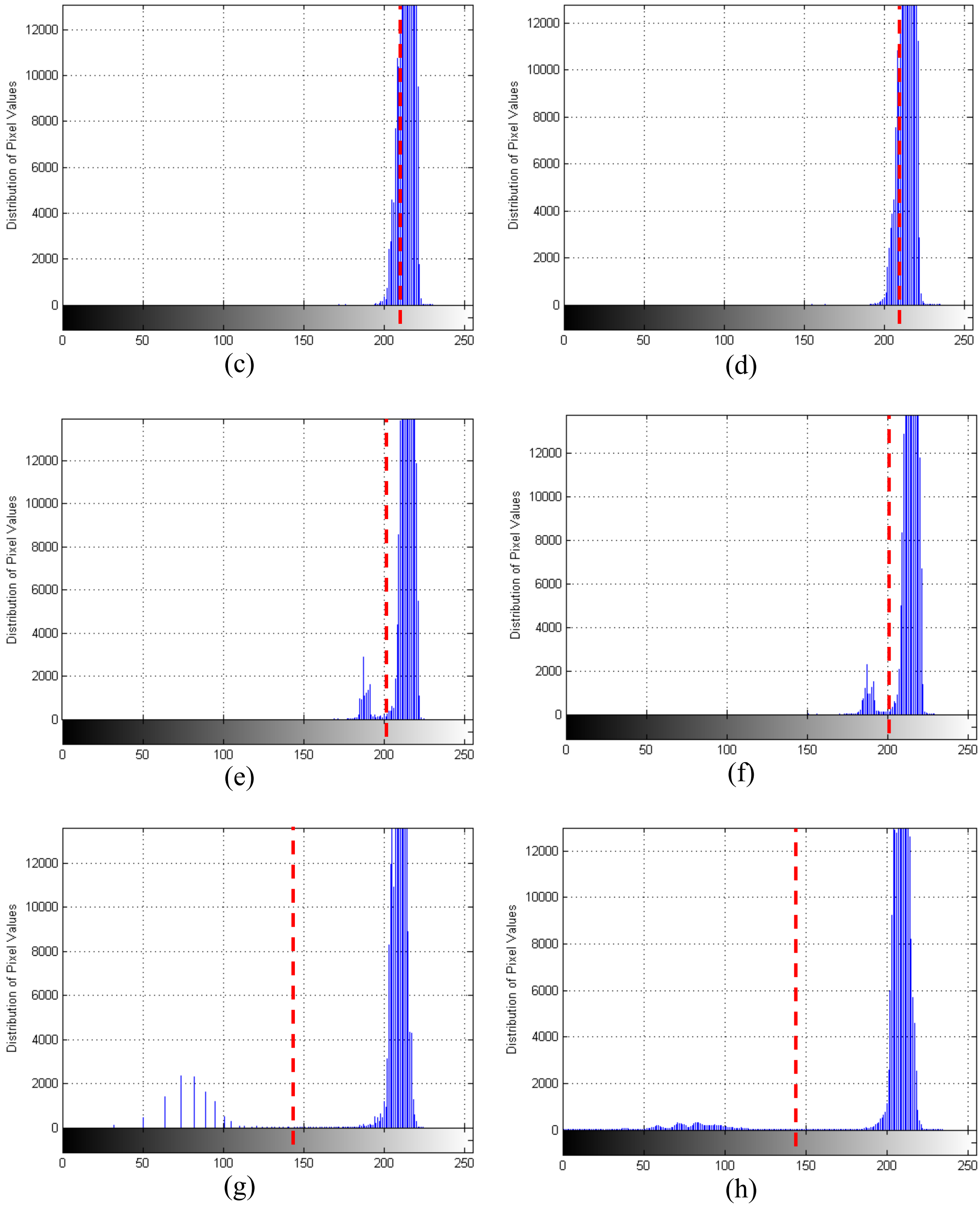
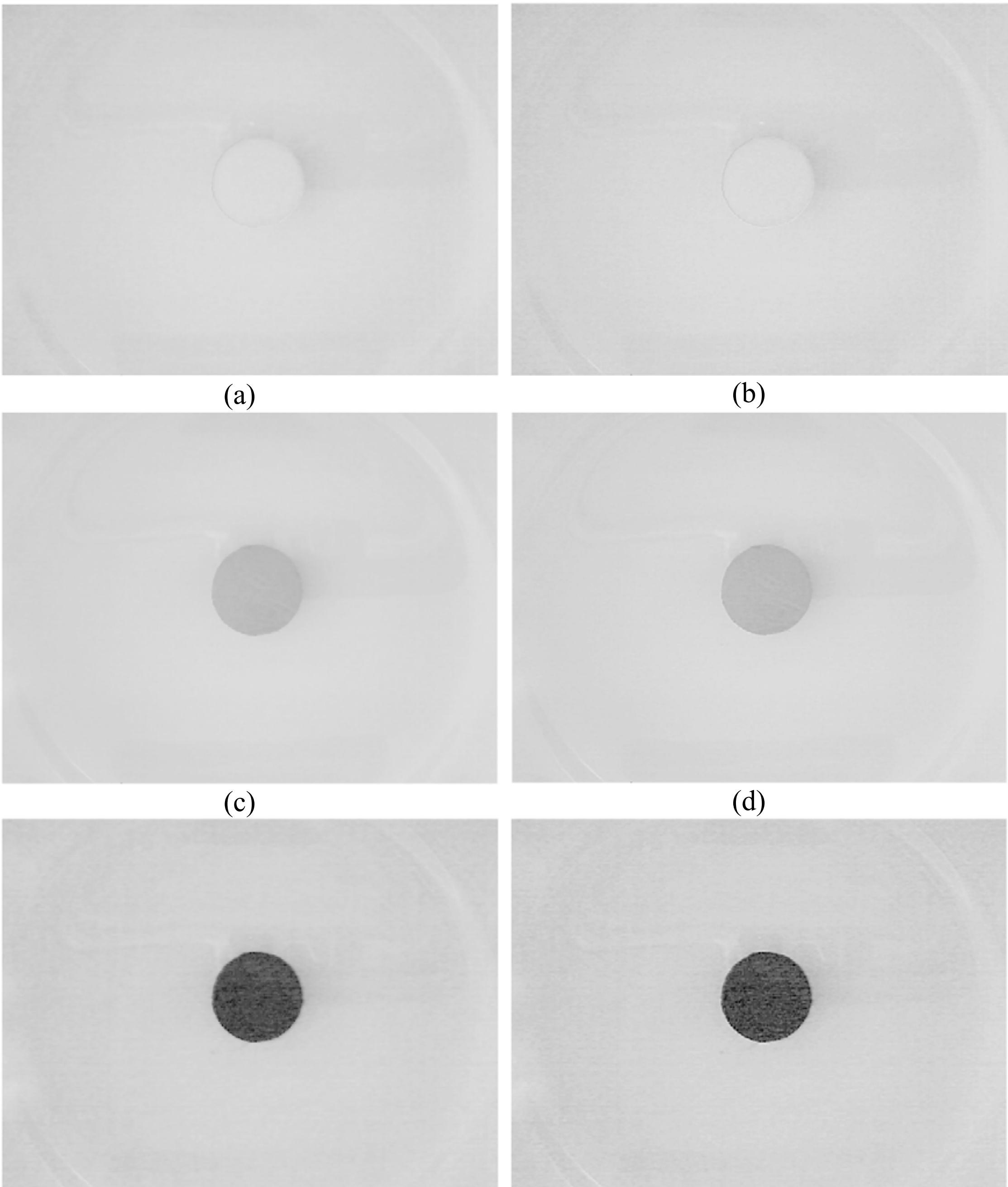


Figure 4.20 The Histograms of Red, Green, and Blue Images Data before and after Sharpening Process; X-axis Indicate the Image Type. (a), and (b) Histogram of Red Channel, (c), and (d) Histogram of Green Channel, and (e), and (f) Histogram of Blue Channel.



(a) (b) (c) (d) (e) (f)

Figure 4.21 The Images of Red, Green, and Blue Channels before and after sharpening Process. (a), and (b) Image of Red Channel, (c), and (d) Image of Green Channel, and (e), and (f) Image of Blue Channel.

4.3.3 Image Contrast Enhancement by Lab Color Space Technique

One of the famous technique to decrease noise, smoothing the image, and enhance colors is to convert image to a color space, in somehow has intensity as one of its components. Color space has different kinds like NTSC, YCBCR, HSV, CMY and International Commission on Illumination family (CIE). Lab color space or in short L*a*b is one of the CIE family which improve the uniform of luminance scale with preserving the original colors. Lab represents in a three-dimensional space, a, and b refer to chromaticity diagram and the third one L describes the lightness which is ranged from 0 to 100, as shown in Figure 4.22. [25, 26]

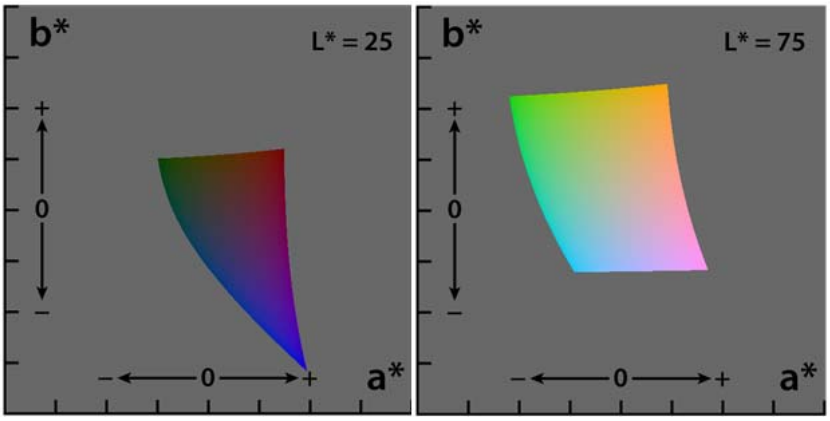


Figure 4.22 Schematic Representation of L*a*b Color Space Technique [26]

Where a domain from green (+) to magenta (-) color, and b scaling from blue (+) to yellow (-) color. The algorithm is quoted from MATLAB which is performed by several steps:

- Convert RGB image to L*a*b as shown in Figure 4.23(b)
- Work on the layer L which is the luminosity layer
- Adjust the colors for the image by increase the value of luminosity to the maximum 100
- Convert L*a*b to RGB color as shown in Figure 4.23(c)

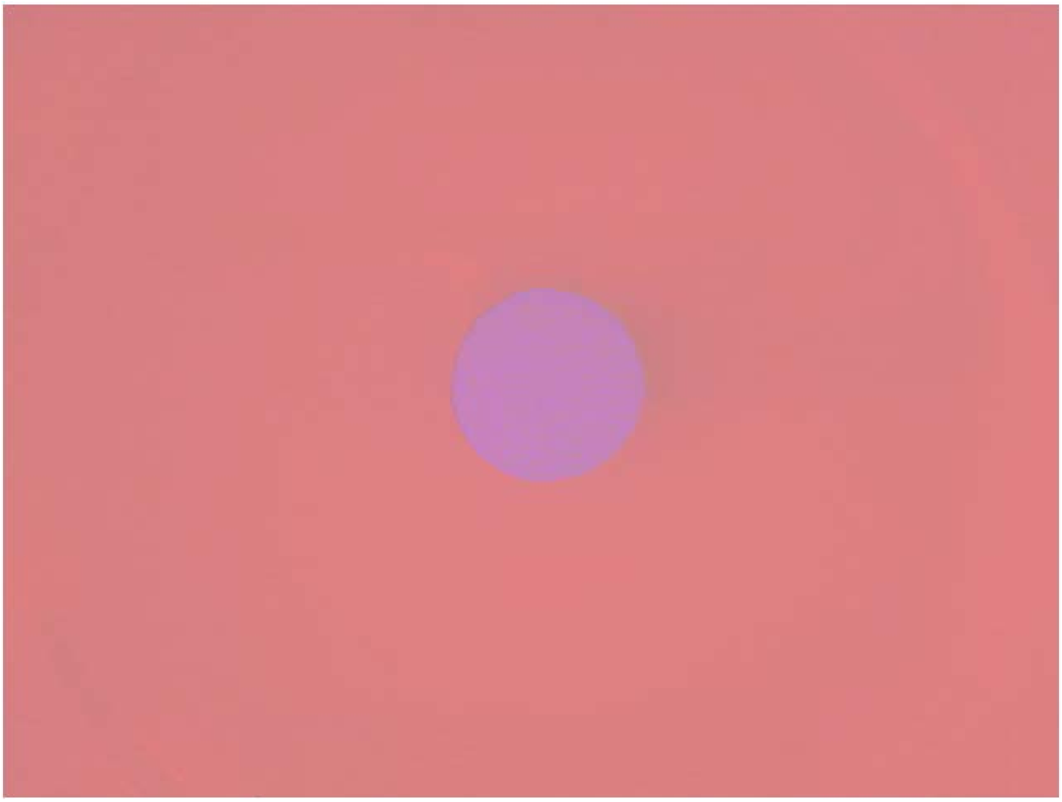
Figure 4.24, the plot presents that colors are almost separated, that means the colors of the image oriented to be pure. Where, the oscillation is decrease in the green channel and increased in the red and blue channels. In Figure 4.25, the smoothing effect appeared clearly in the indexed image.

Table 4.4 is displayed the thresholding values for gray and channels images. Where, it is seen that the values decreased.

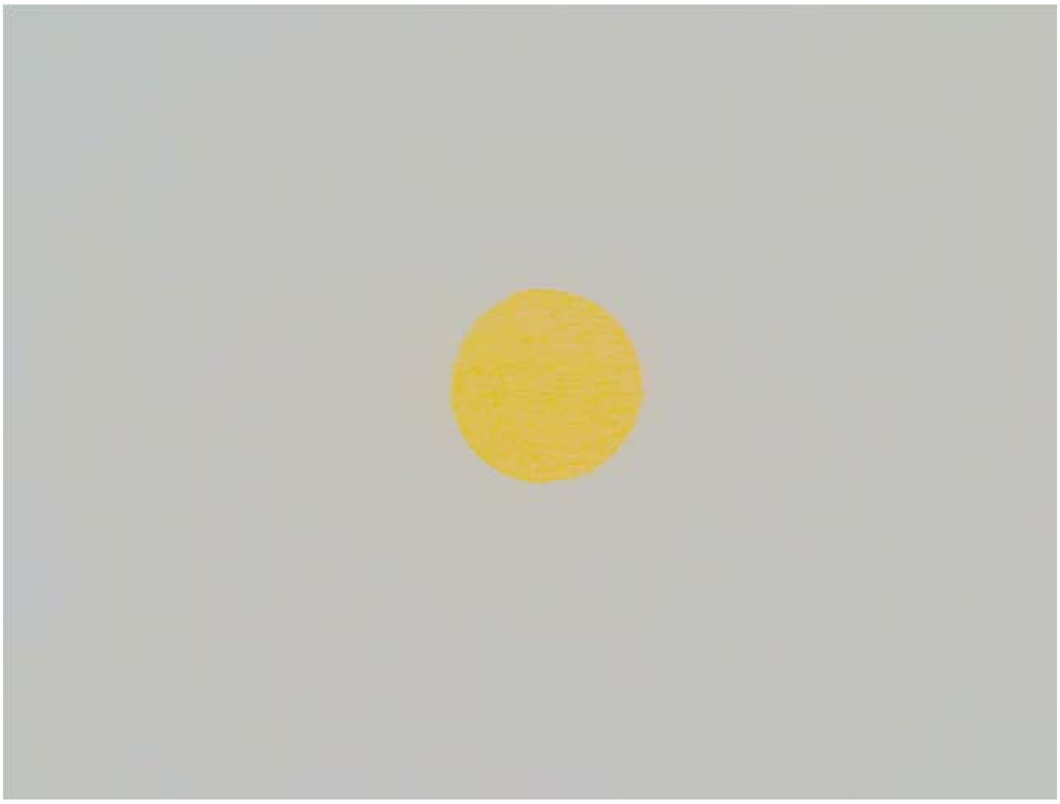
In Figure 4.26 and Figure 4.27 the histogram diagram for each channel is changed, where it is seen that the object almost disappears in the green channel and come into view in the red channel. Furthermore, the channels and the gray histogram clears that the width of bands for every channel decreases. Moreover, in the red channel in somehow contains two separated bands one act as the object and other the background. As a result, the object has less noise and almost clearly appeares in all channels.

As mentioned above the object and background have different colors in the red and blue channels as shown in Figure 4.28(a) and Figure 4.28(c), and close colors in the green channel as seen in Figure 4.28(b).

(a) Image Sharpening Enhancement



(b) Convert RGB To L*a*b Colorspace



(c) Convert L*a*b To RGB Color

Figures 4.23 Images of Lab Color Space Steps Enhancement Technique

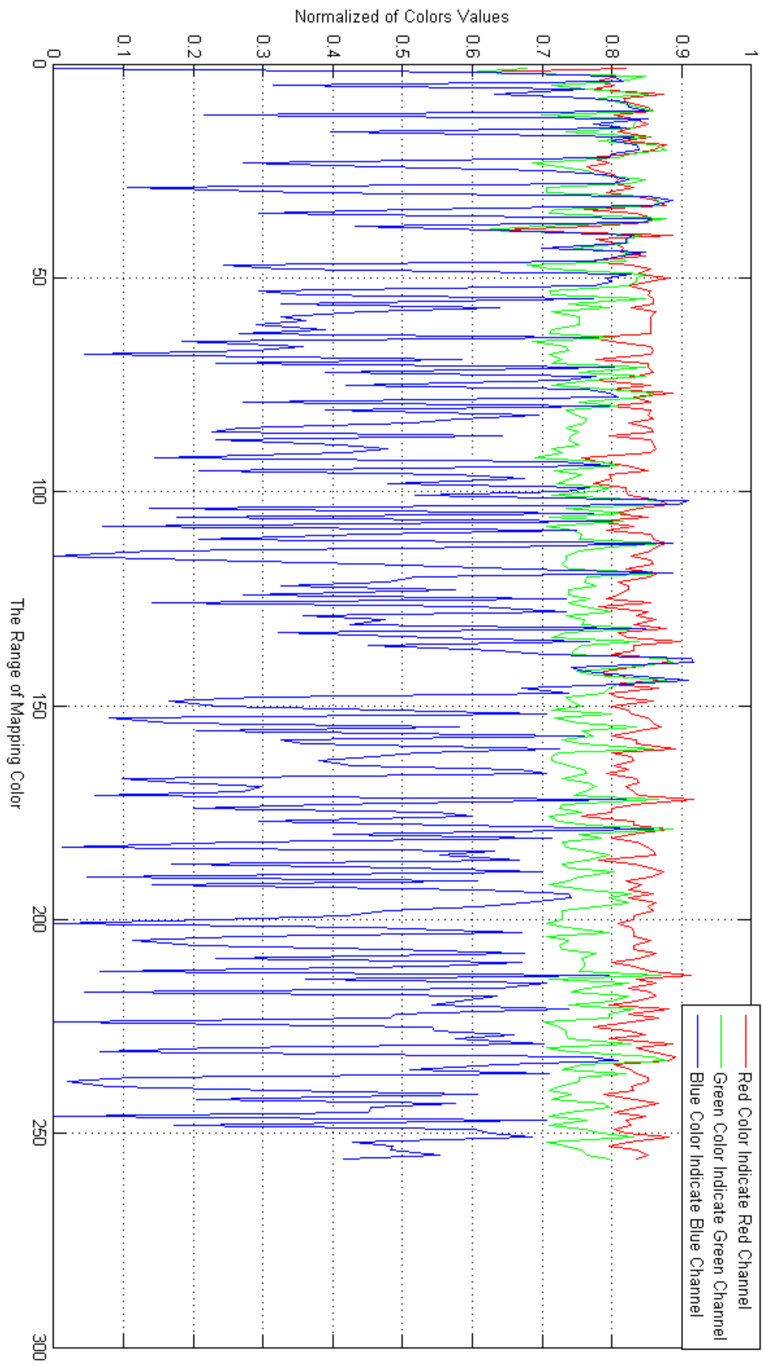

Normalized of Colors Values
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
The Range of Mapping Color
0
50
100
150
200
250
300
Red Color Indicate Red Channel
Green Color Indicate Green Channel
Blue Color Indicate Blue Channel

Figure 4.24(a)

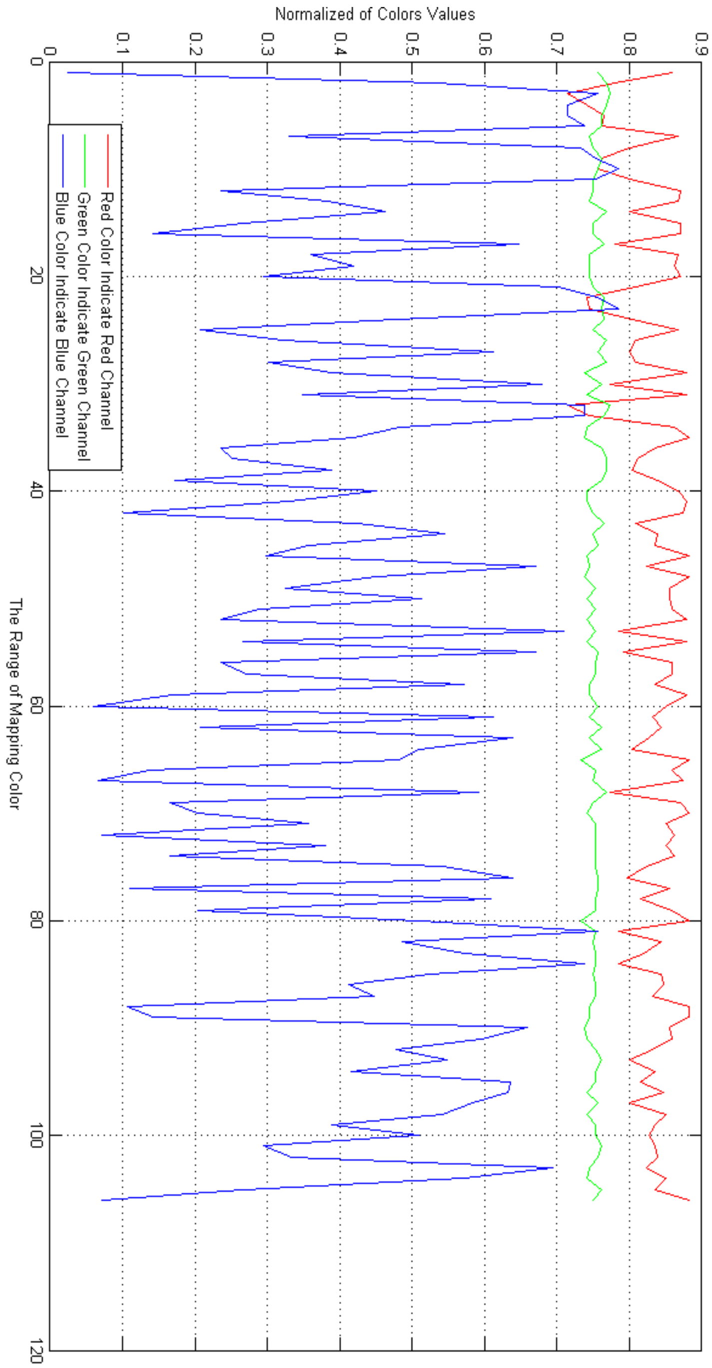
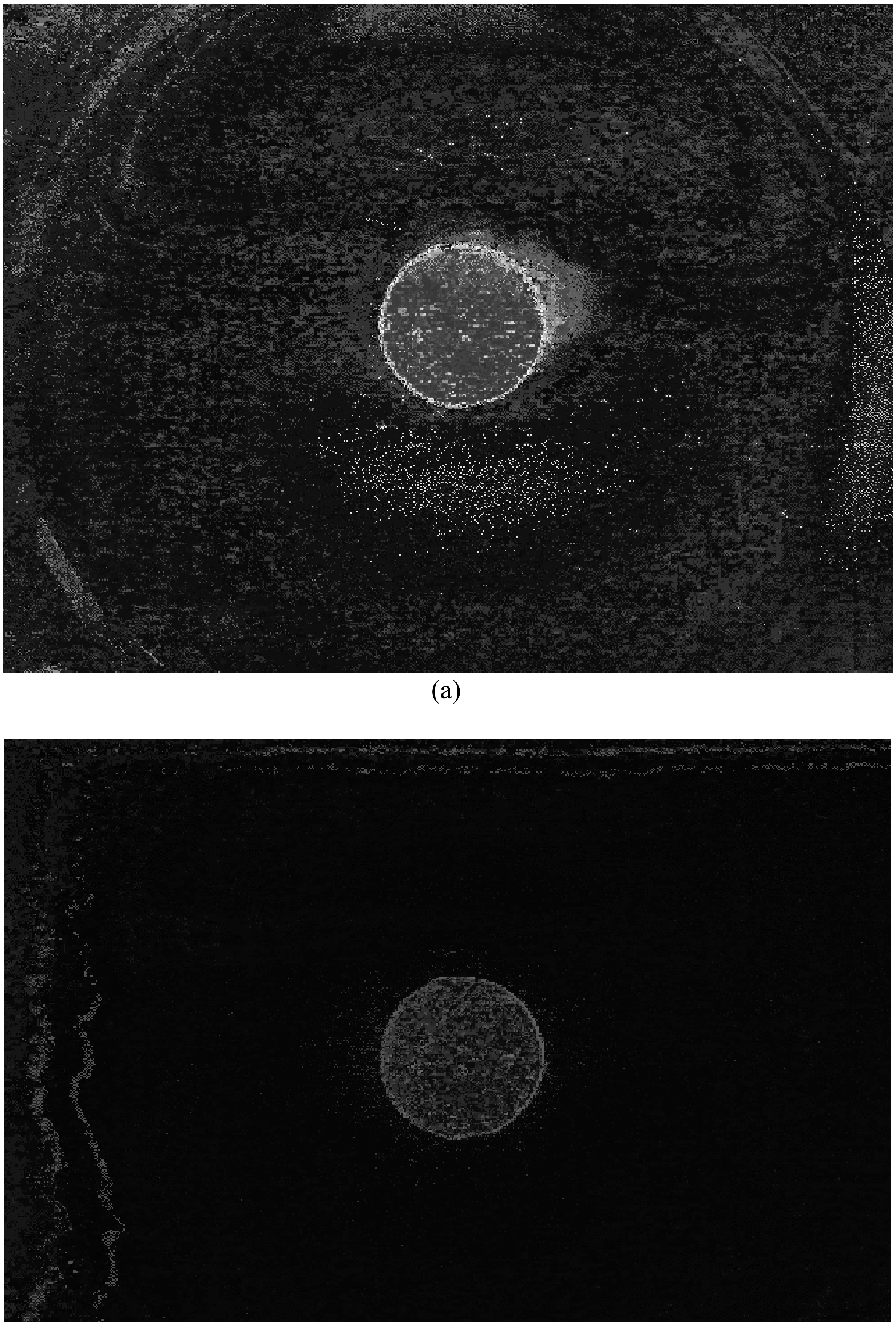


Figure 4.24(b)

Figure 4.24 Plots of Red, Green, and Blue Colormap (a) before and (b) after Lab Colorspace Process



(a)

(b)

Figure 4.25 Indexed Image (a) before and (b) after Lab Colorspace Process

Table 4.4 Thresholding Values before and after Lab Color Space Process

Types	RGB	Gray	Red	Green	Blue
Thresholding (Before)	0.5725	0.7804	0.8353	0.7882	0.5647
Thresholding (uint8 / Before)	146	199	213	201	144
Thresholding (After)	0.5353	0.7451	0.8118	0.7608	0.5353
Thresholding (uint8 / After)	136.5	190	207	194	136.5

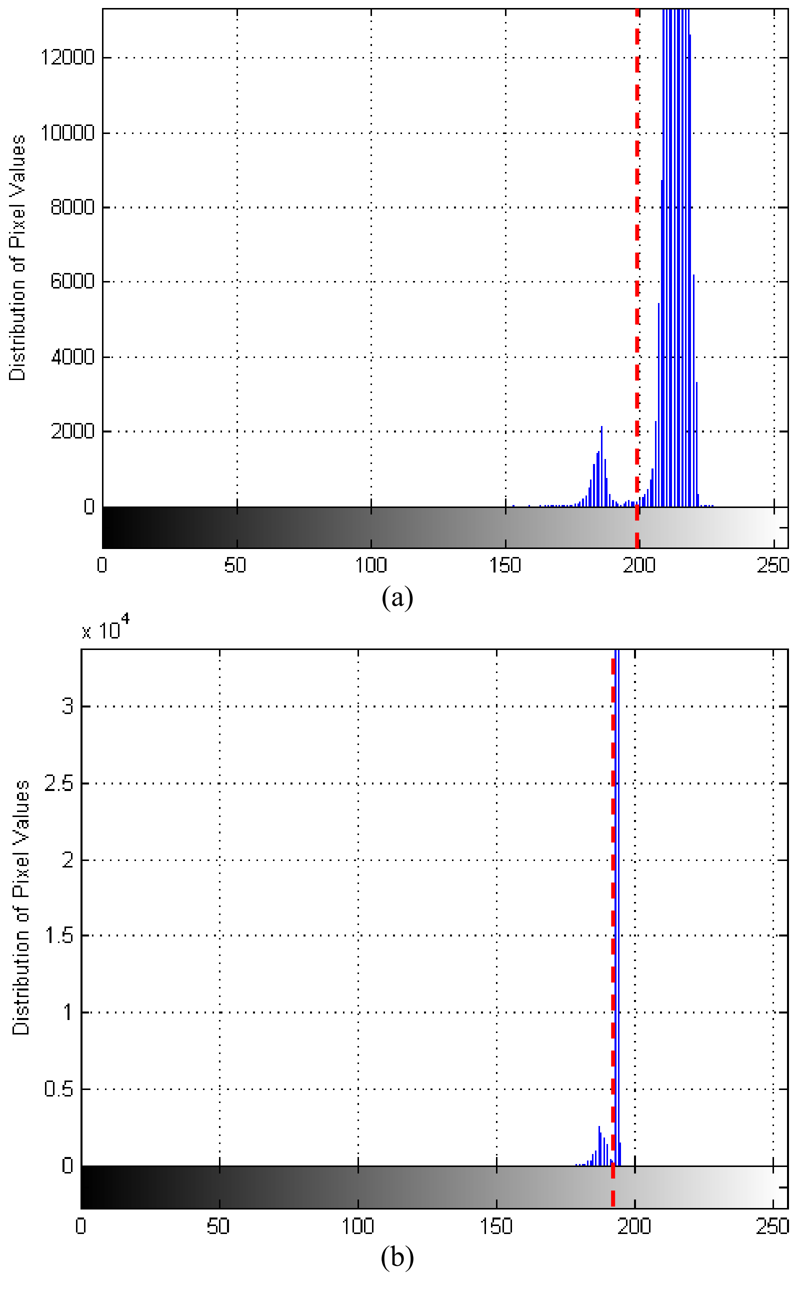


Figure 4.26 The histogram of Gray Image Data before and after Lab Enhancement Technique; X-axis Indicate the Image Type

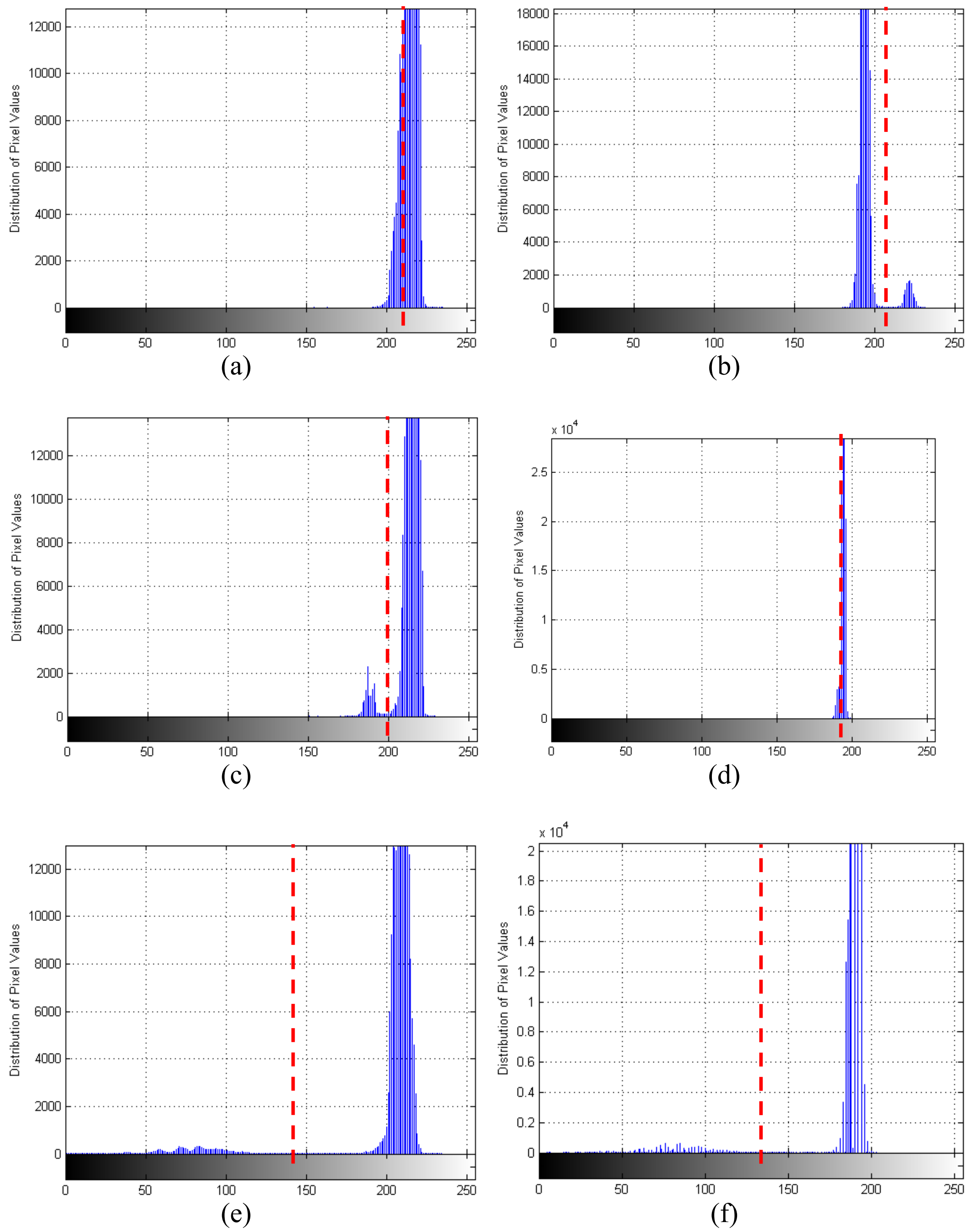
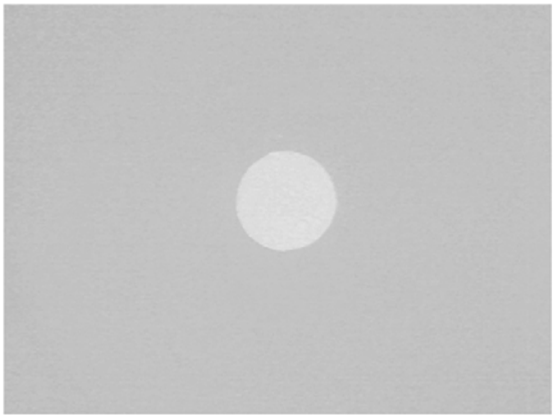


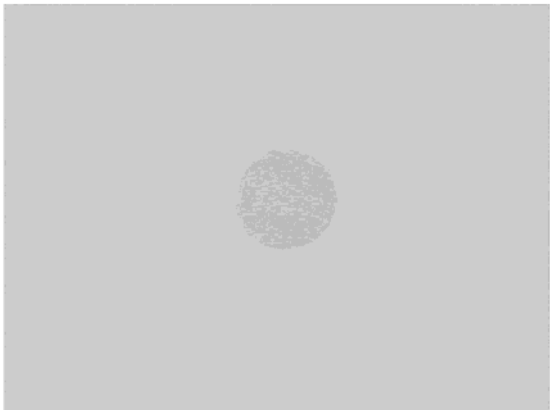
Figure 4.27 Histograms of Red, Green, and Blue Images Data before and after Sharpening Process; X-axis Indicate the Image Type. (a), and (b) Histogram of Red Channel, (c), and (d) Histogram of Green Channel, and (e), and (f) Histogram of Blue Channel.

(a)

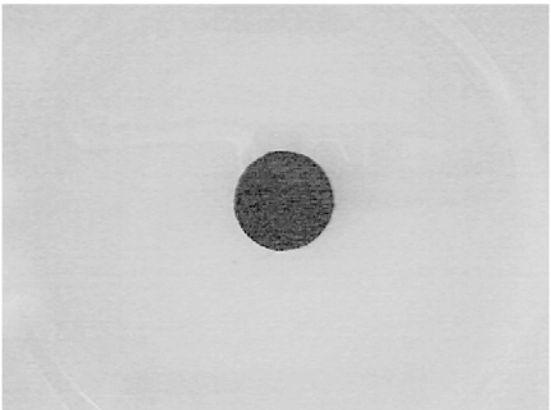


(b)

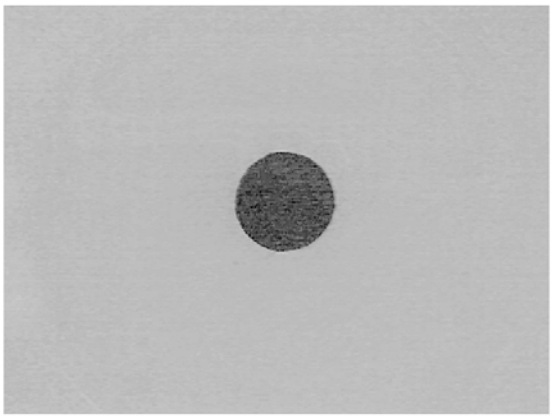
(c)



(d)



(e)



(f)

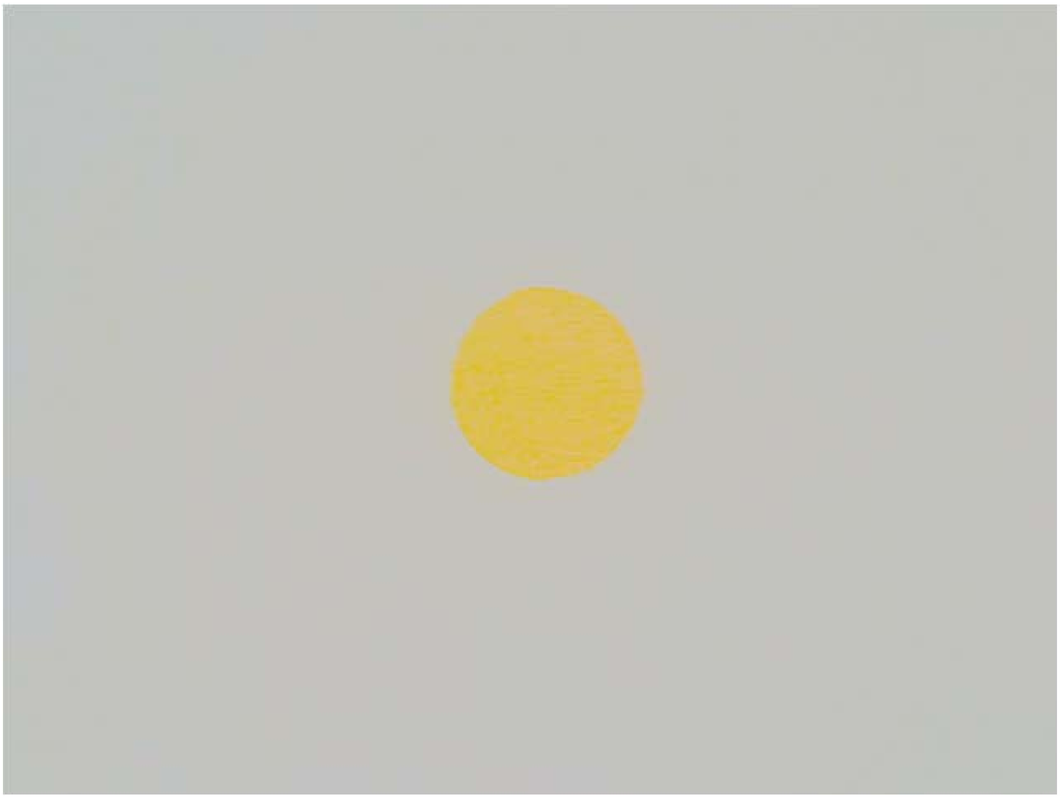
Figure 4.28 The Images of Red, Green, and Blue Channels before and after Sharpening Process. (a), and (b) Image of Red Channel, (c), and (d) Image of Green Channel, and (e), and (f) Image of Blue Channel.

4.3.4 Filtering Red, Green, and Blue Channels Separately

The RGB image is a color model where is red, green, and blue light added together in various ways to reproduce a broad array of colors.

The image coming out after Lab enhancement technique has a noise in each channel, also the features are not improve as shown in Figure 4.25(b). Unfortunately, treatment image as one part (color image) is so difficult, since almost of the noise filtering can be applied on the gray or binary level. However, the best and easy way to treatment the noise of the image is to filter each channel separately, and combined them. Mainly, filters can be classified into two types, linear and nonlinear filters. Researchers have invented a large numbers of filters using different techniques, such as blocking, and intensity.

In this research, filtering a red, green, and blue channels are done by using Median filter, which, as its name implies, replaces the value of a pixel by the median of the intensity values in neighborhood of that pixel [1]. In the image processing, median filter is a perfect operation to remove the noise especially salt and pepper noise, and lesser blurring than linear smoothing filters. It is a typical nonlinear process step to improve the Lab result as shown in Figure 4.29(b), where the edge of the object became sharper than the image in Figure 4.29(a). Figure 4.30 shows the plot of the colormap, where the interacted among the channels are decreased and the amplitude of the highest intensity value reduced. Since the oscillation of the green channel is decreased, the object is embedded in the background. Figure 4.31 shows the median effect on the feature of the whole image where it improved and the noise reduced. From Table 4.5 can be seen the sharp decline in the value of green channel, this indicate the object will be embedded in the background. Figure 4.32 and Figure 4.33 show the histogram of image data where the band becomes less and extended along the histogram. Figure 4.34 show clearly the object appeared in all channels, in spite of the object is paled in the green channel.


(a)

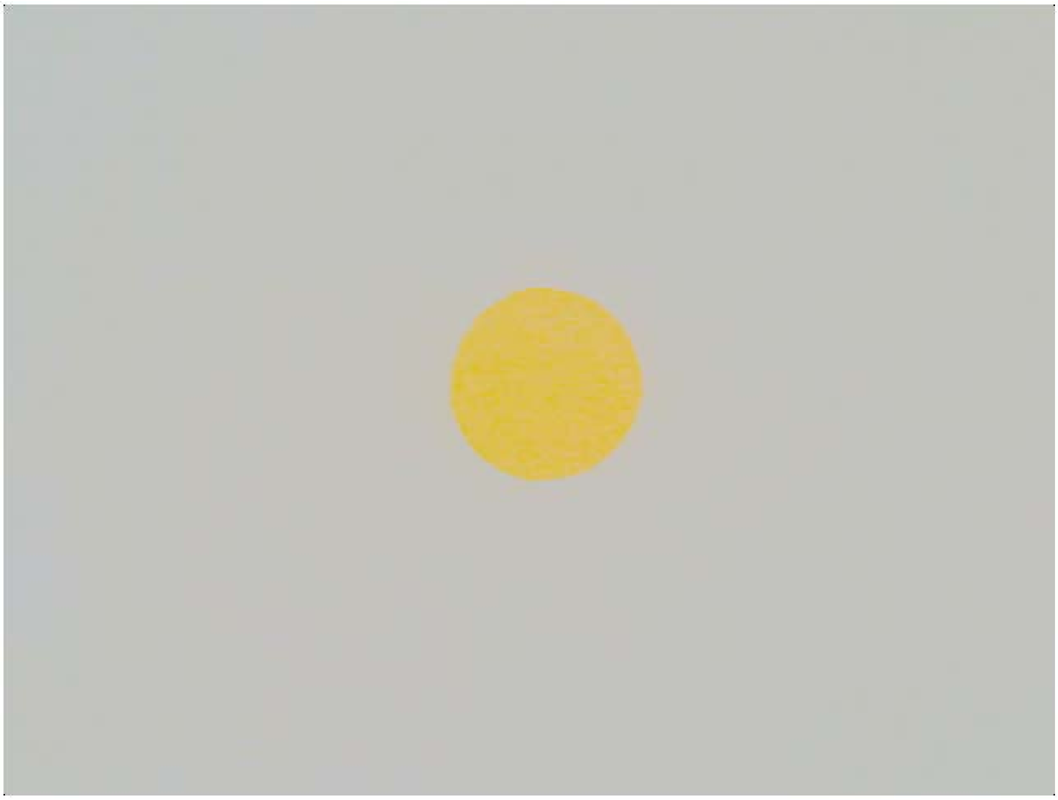

(b)

Figure 4.29 Samples of Images (a) before and (b) after Median Filter Process

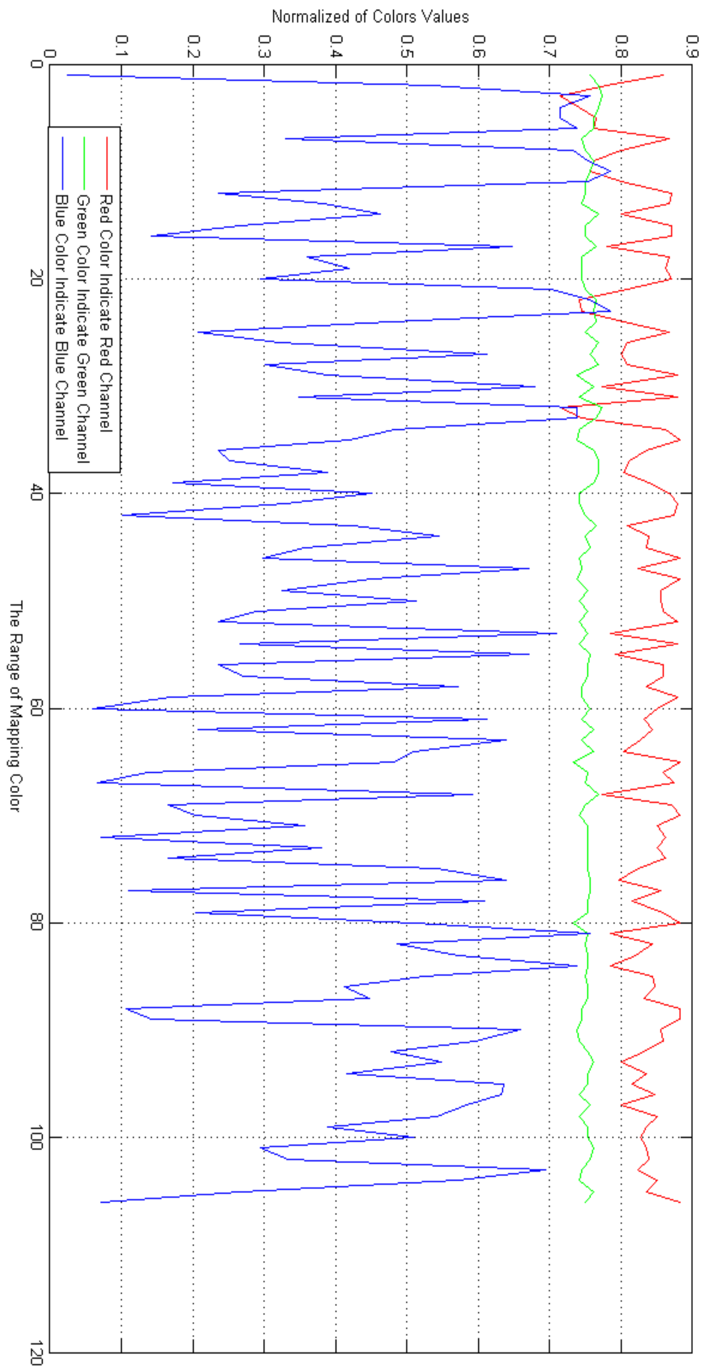

Normalized of Colors Values
The Range of Mapping Color
Red Color Indicate Red Channel
Green Color Indicate Green Channel
Blue Color Indicate Blue Channel
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
20
40
60
80
100
120

Figure 4.30(a)

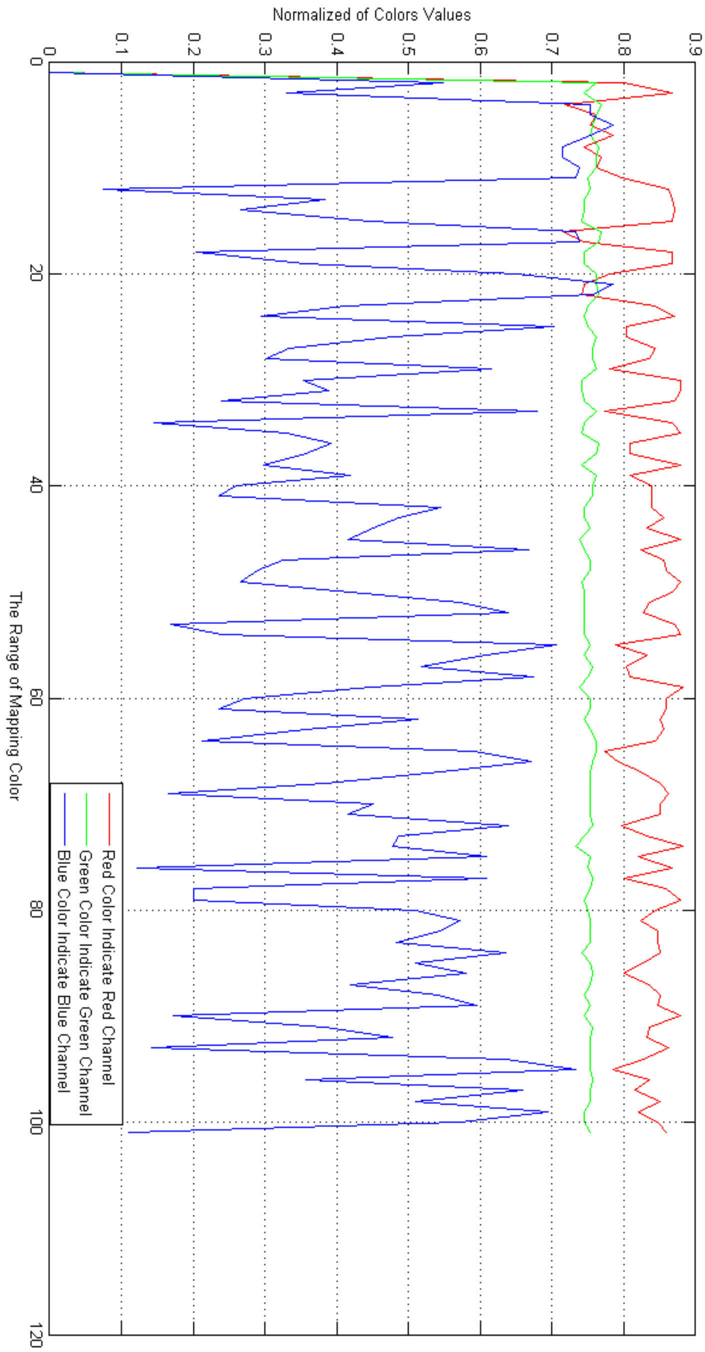
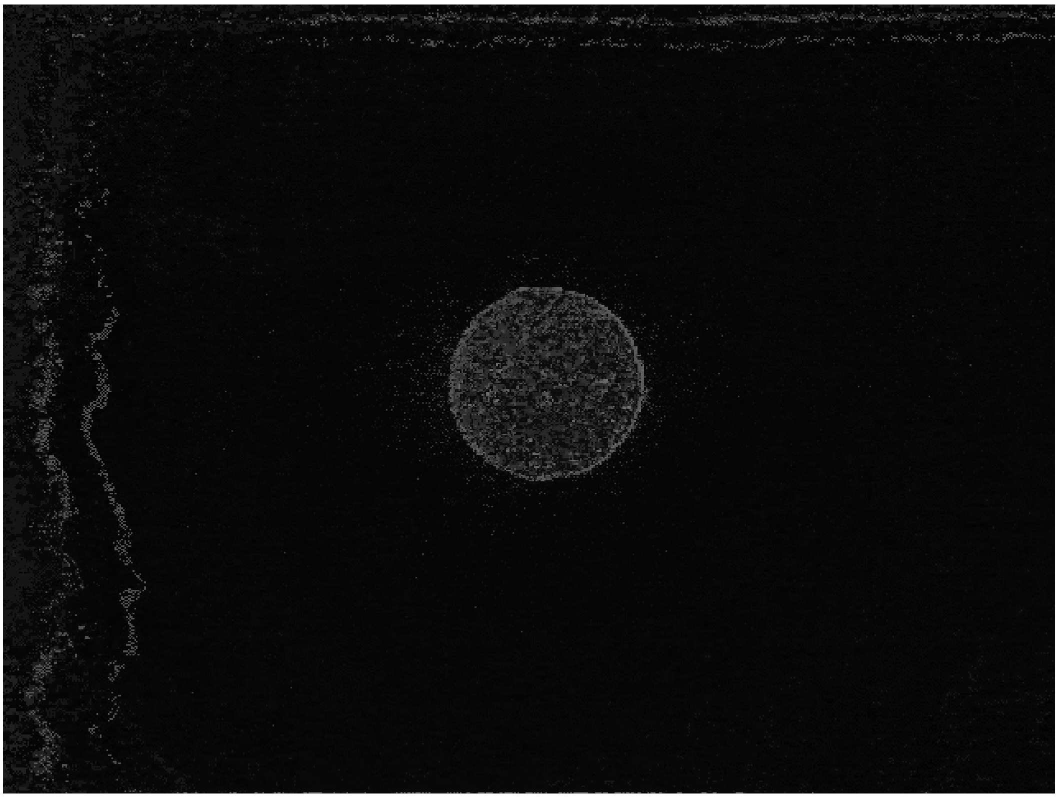
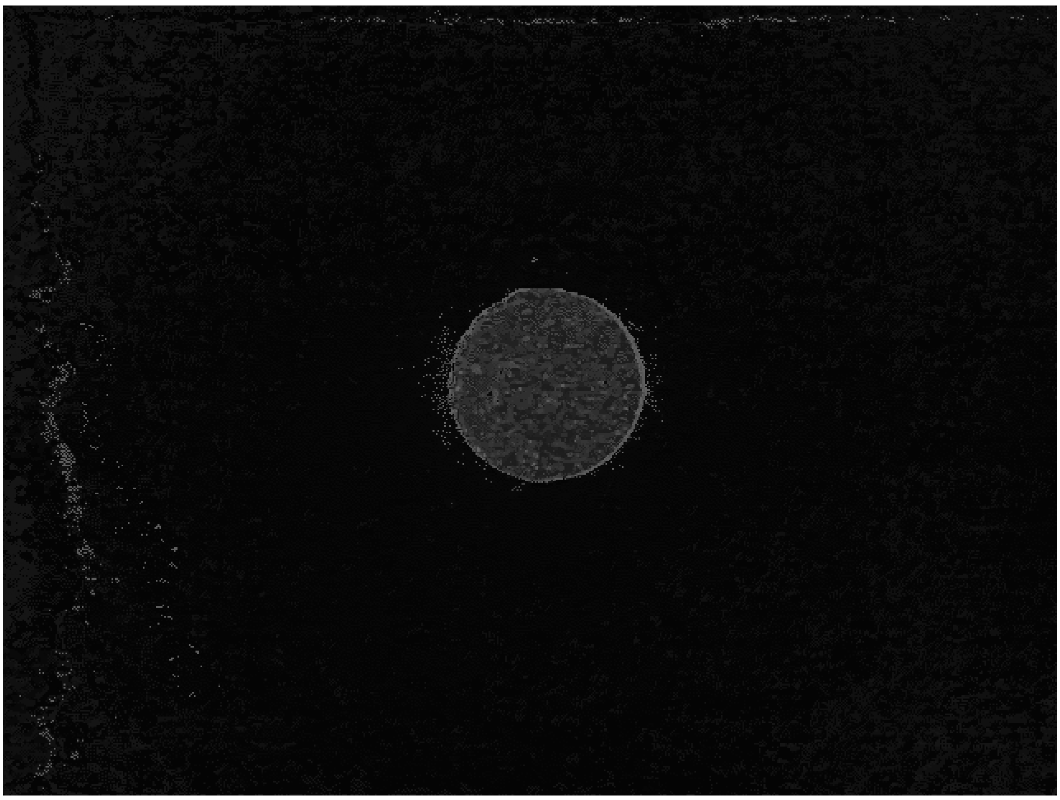


Figure 4.30(b)

Figure 4.30 Plots of Red, Green, and Blue Colormap before and after Median Filter Technique



(a)

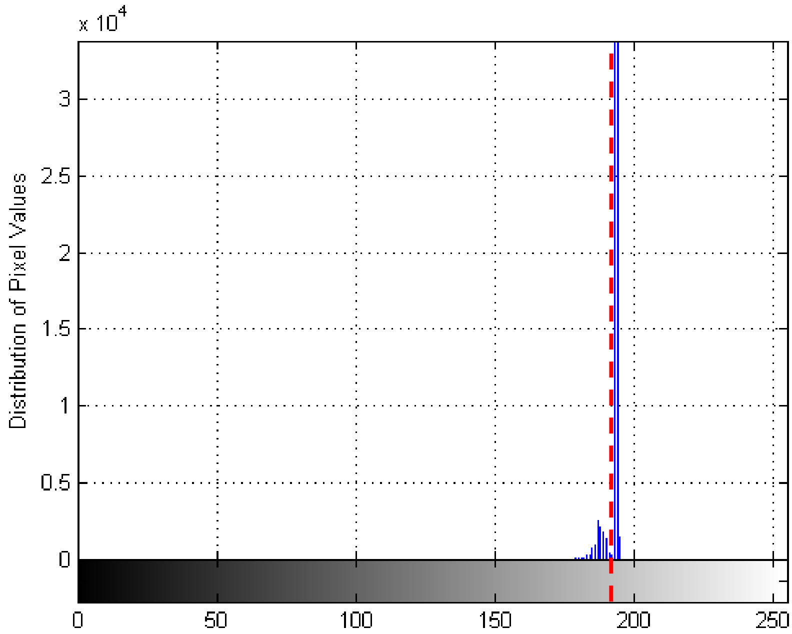


(b)

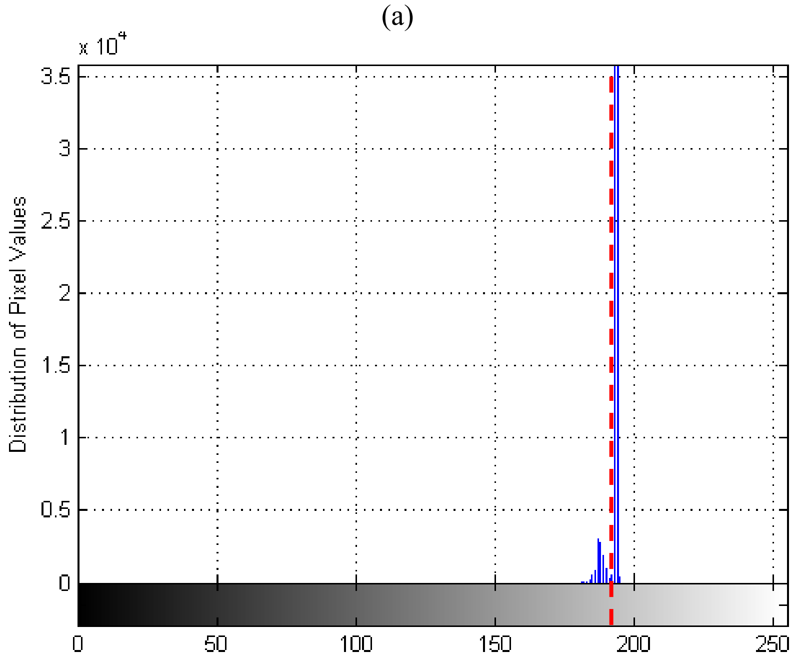
Figure 4.31 Indexed Image (a) before and (b) after Median Filtering Process

Table 4.5 Thresholding Values before and after Filtering Process

Types	RGB	Gray	Red	Green	Blue
Thresholding (Before)	0.5353	0.7451	0.8118	0.7608	0.5353
Thresholding (uint8 / Before)	136.5	190	207	194	136.5
Thresholding (After)	0.5412	0.7451	0.8118	0.3647	0.5353
Thresholding (uint8 format-After)	138	190	207	93	136.5



(a)



(b)

Figure 4.32 The histogram of Gray Image Data before and after Median Filter Technique; X-axis Indicate the Image Type

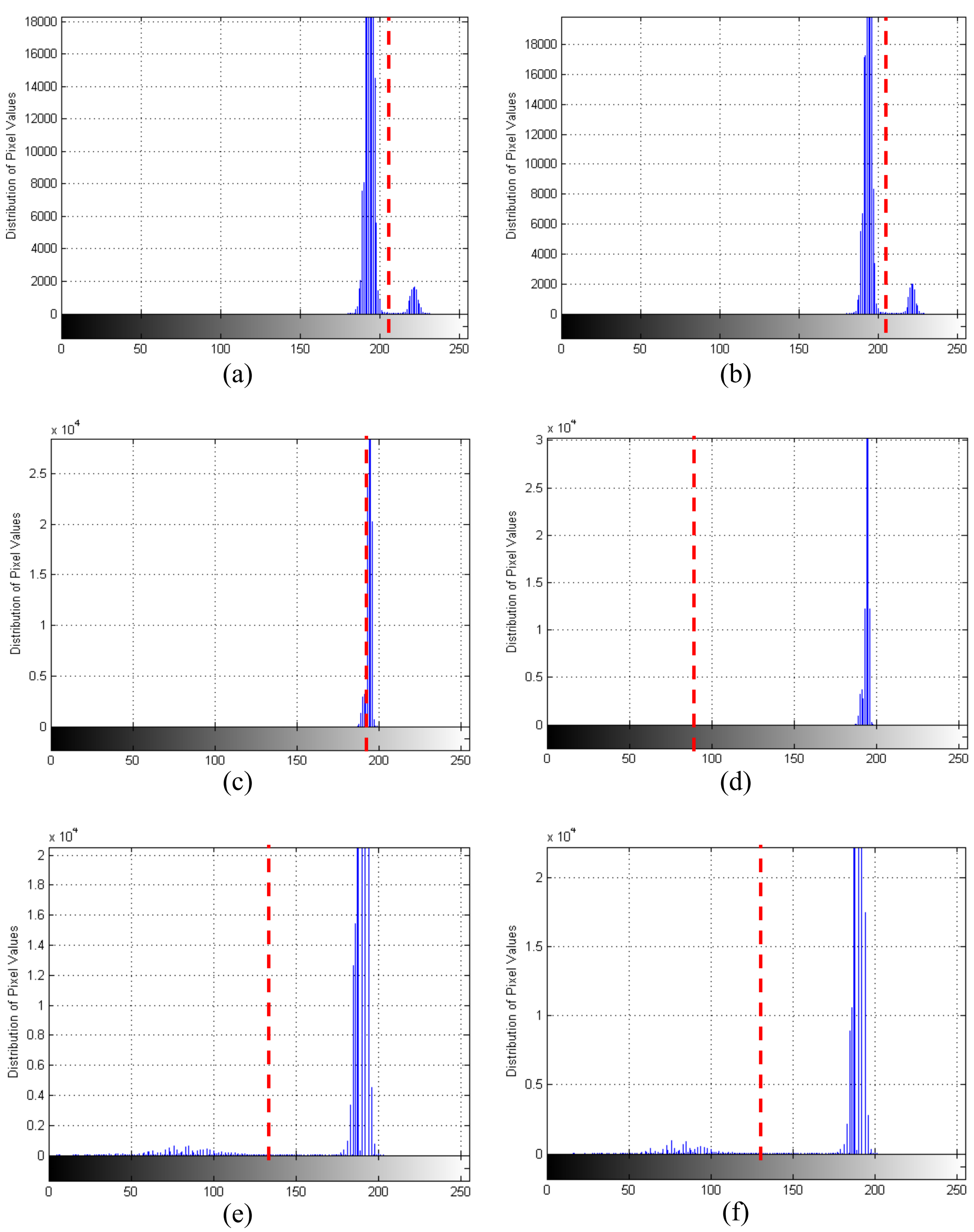
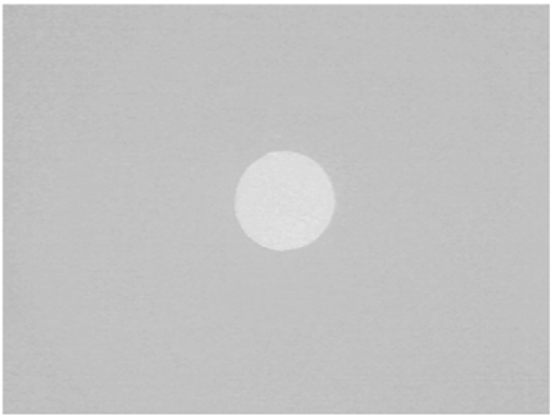
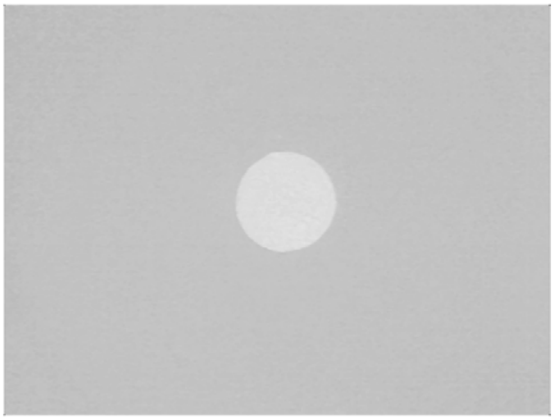


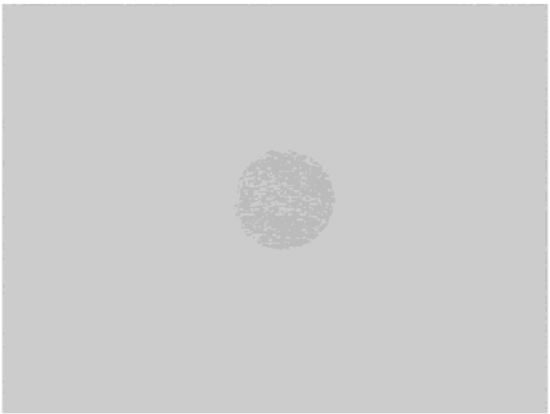
Figure 4.33 Histograms of Red, Green, and Blue Images Data before and after Median Filter Technique; X-axis Indicate the Image Type. (a), and (b) Histogram of Red Channel, (c), and (d) Histogram of Green Channel, and (e), and (f) Histogram of Blue Channel.



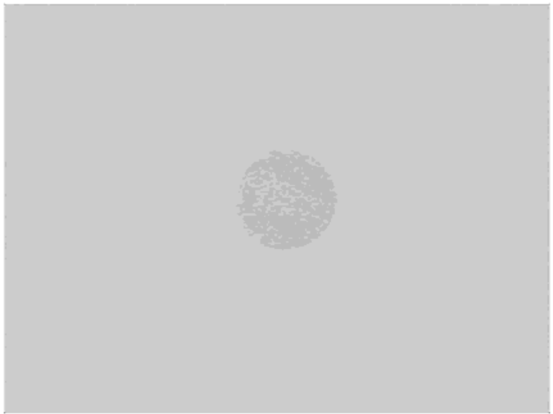
(a)



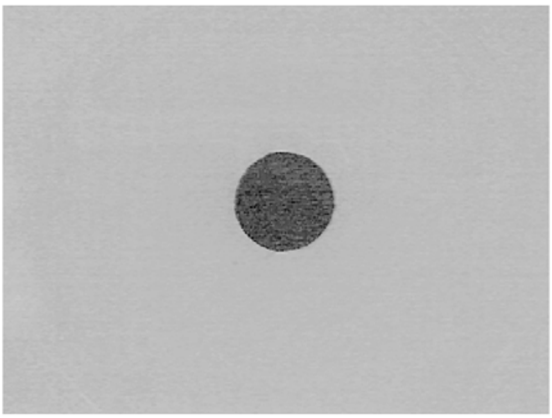
(b)



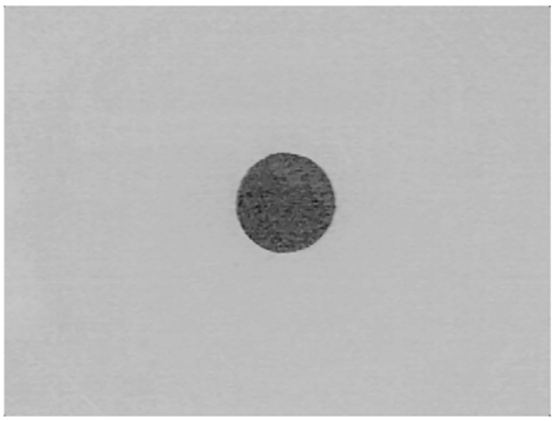
(c)



(d)



(e)



(f)

Figure 4.34 The Images of Red, Green, and Blue Channels before and after Median Filter Process. (a), and (b) Image of Red Channel, (c), and (d) Image of Green Channel, and (e), and (f) Image of Blue Channel.

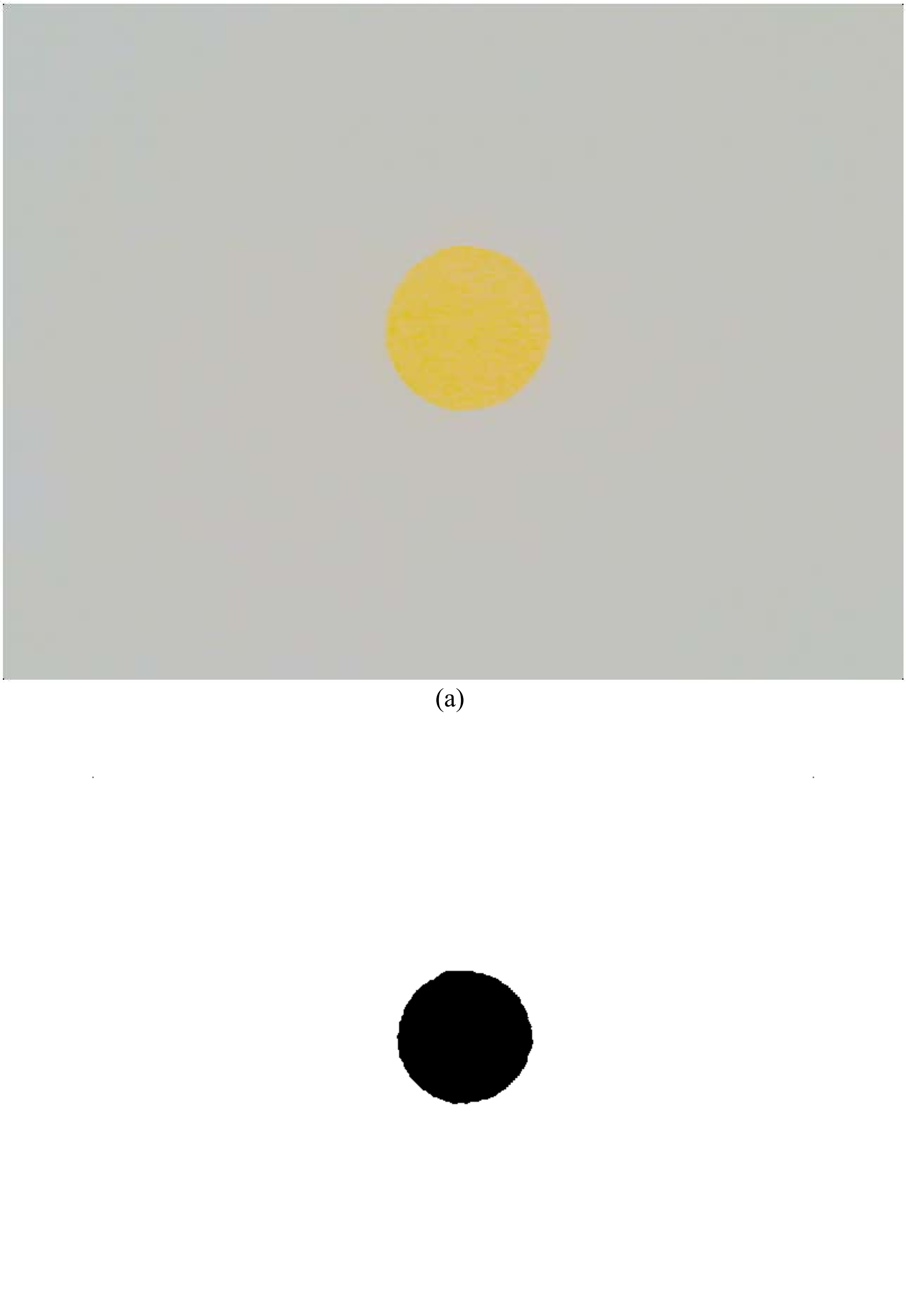
4.3.5 Segmentation of Color Image

Segmentation of a digital image is one of the most challenging tasks, where it simplify and/or change the features of an image into sets to identify the set of properties. Typically, many methods used are based on histogram, edge, region, clustering, and texture. Despite, almost of them couldn't be suitable to consider positive for long process of images. In this study, segmentation quoted from Digital Image Processing Using MATLAB book, which based on using Mahalanobis or Euclidean. Segmentation code by Mahalanobis or Euclidean methods consists of several steps:

- Construct a binary mask of a region of interest (ROI).
- Compute the mean vector and covariance matrix of the points in the ROI.
- Calculate the thresholding value.
- Using Euclidean method to segment the image.

It is worthy to mention that Standard deviation is important parameters in this algorithm to get valid results.

Figure 4.35 shows the filtering image and the result of the segmentation technique, where the object appeared as a black color, and background as a white color.



(a)

(b)

Figure 4.35 Sample Images of (a) before and (b) after Segmentation Technique

4.3.6 Calibration image

Section 3.6.2, calibration is so important step to remove the distortion of the shape as shown in the Figure 4.36. However, if the camera has a good specifications to treatment the dismiss shape, the effect of the calibration process is not appearing clearly within the process as depicted in Figure 4.37.

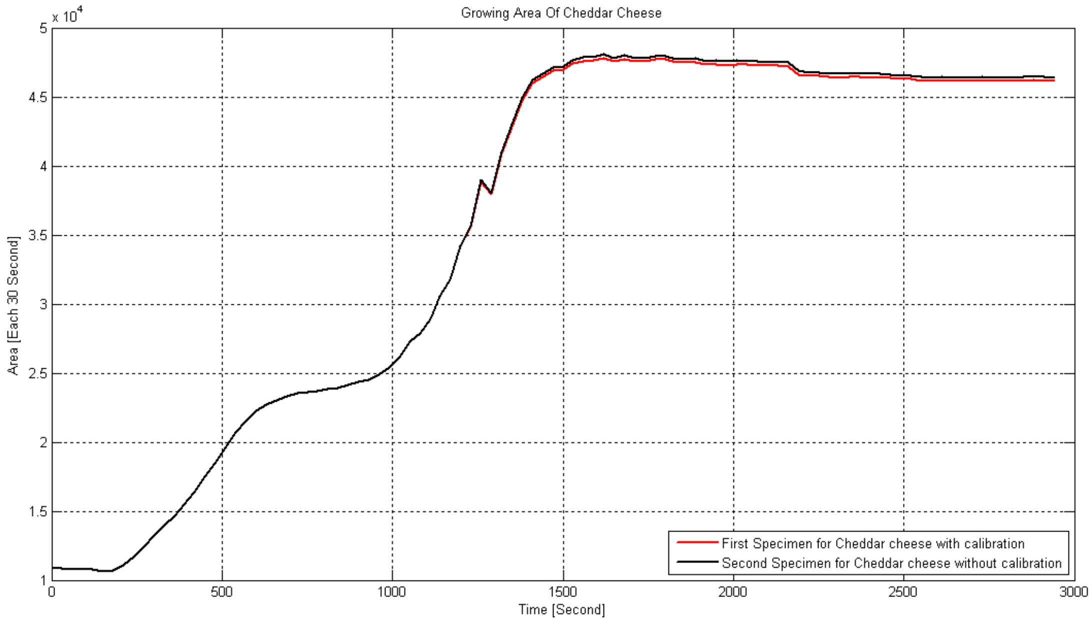


Figure 4.36 The Difference Between Calibration and Un-calibration Images

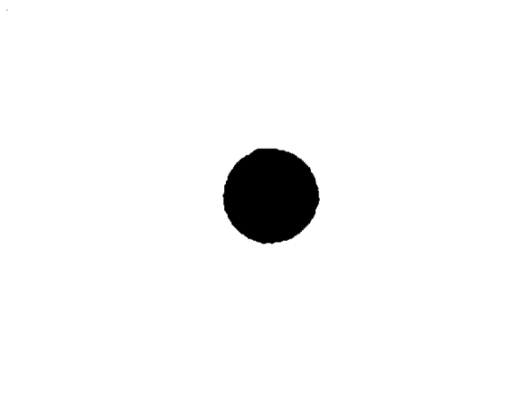


Figure 4.37(a) Segmentation Image

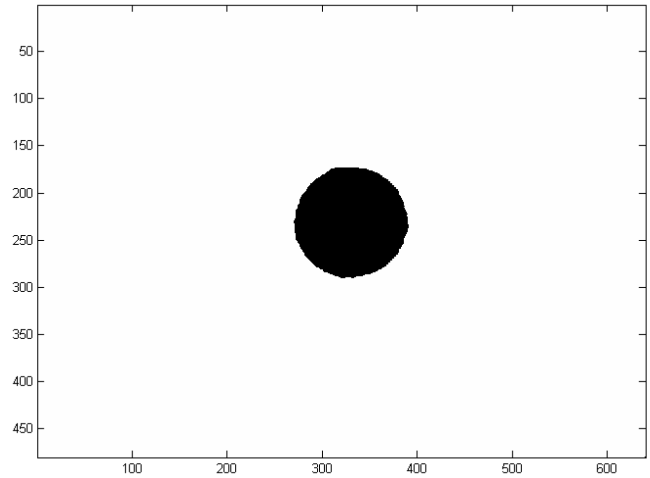


Figure 4.37(b) Distortion Image

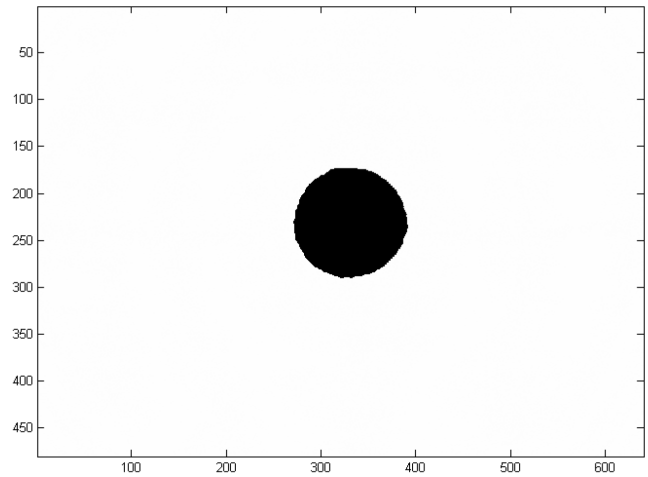


Figure 4.37(c) Undistortion Image

Figure 4.37(d) Calibration Image

Figure 4.37 Images of Calibration Steps

4.3.7 Morphology Operations and Quality Estimation

The last step is to improve the representation and description of the edge of the cheese. Morphology operation is a powerful approach to numerous image processing problems. Opening and closing operations are one of the important techniques to smooth the object. In the one hand, opening operation is the process to smooth the outline of the object, breaks the narrow isthmuses, and removes thin protrusions. While, closing operation is also tend to smooth the object but in the opposed way. Before applying operations of morphology, the image has to be converting to binary. Where, morphology operation effect become clearly and better when the image is binary consists from 0 and 1. Figure 4.38(a-m) shows the effect of the morphology operation on the image. Figure 4.38(a) show the rolling of the structure elements of the open operation along the inner edge, which is followed by complement the image to the negative image as shown in Figure 4.38(b), to apply the open operation for the inner edge as shown in Figure 4.38(c), but in the complement part. Then, filling the holes which is the background region surrounded by a connected border of foreground pixels, will be remove the black dots in the white region as shown in Figure 4.38(d). Figure 4.38(e) show the close operation for the outer edge, where it is followed by open operation for inner edge as display in Figure 4.38(f). Figure 4.38(g) show the median filter technique to remove the noise. After that, convert the image to the original case as shown in Figure 4.38(h) to apply the open and close operation on the inner and outer edge as shown in Figure 4.38(i) and Figure 4.38(j). Then complement the image as shown in Figure 4.38(k) and apply opening operation on the inner edge as shown in Figure 4.38(l). Finally, plot the boundary line on the original image prove that the object is extracted from the background perfectly.

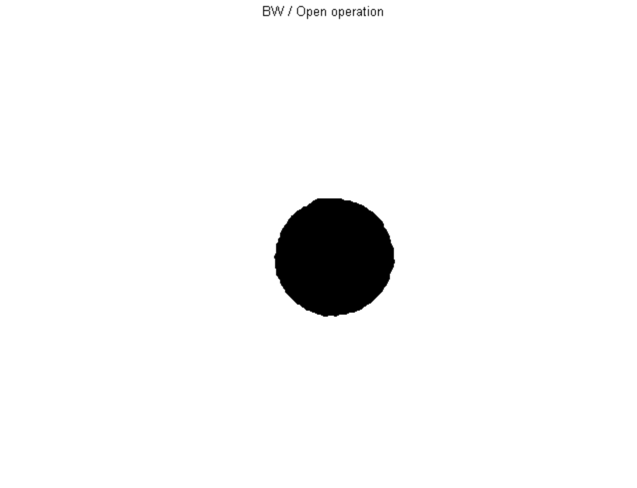


Figure 4.38(a)

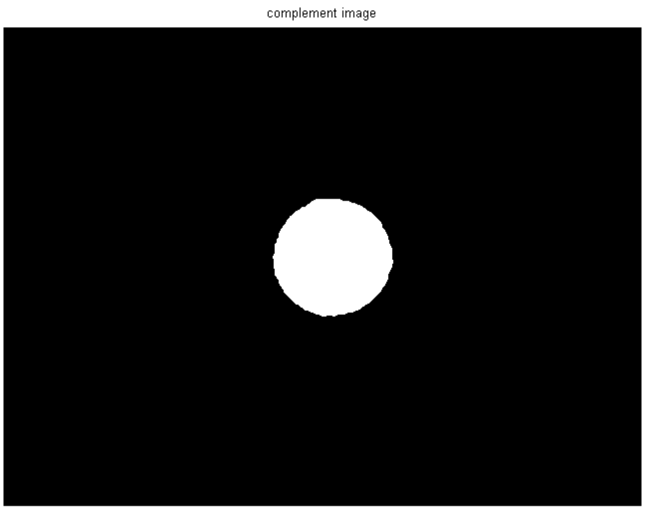


Figure 4.38(b)

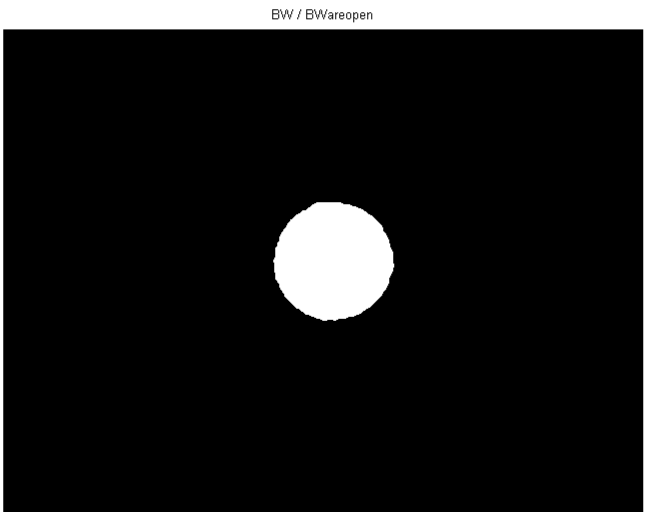


Figure 4.38(c)

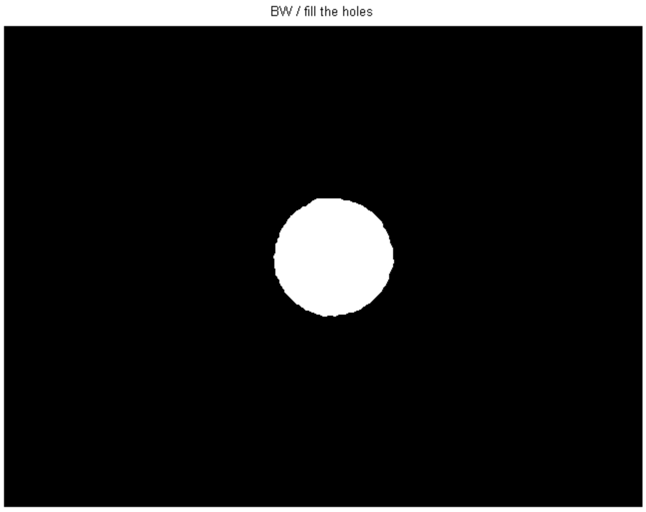


Figure 4.38(d)

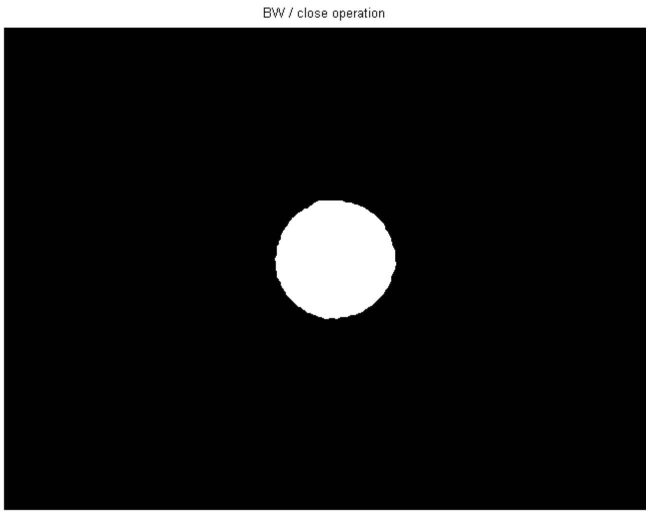


Figure 4.38(e)

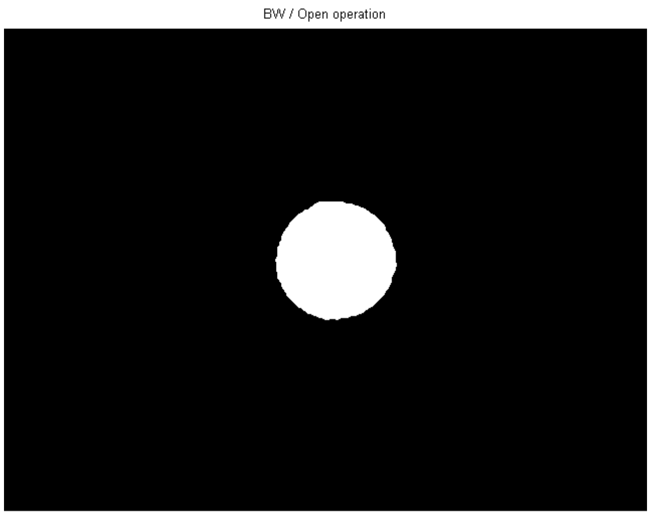


Figure 4.38(f)

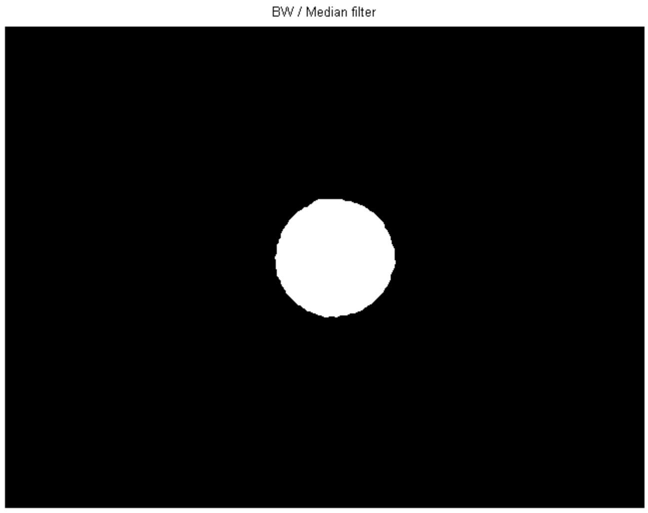


Figure 4.38(g)

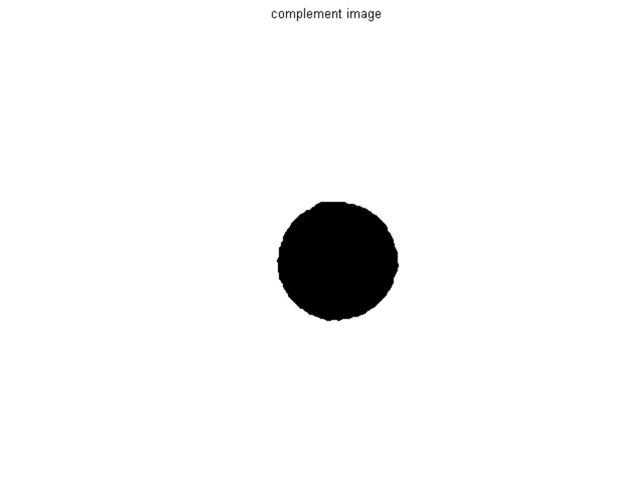


Figure 4.38(h)

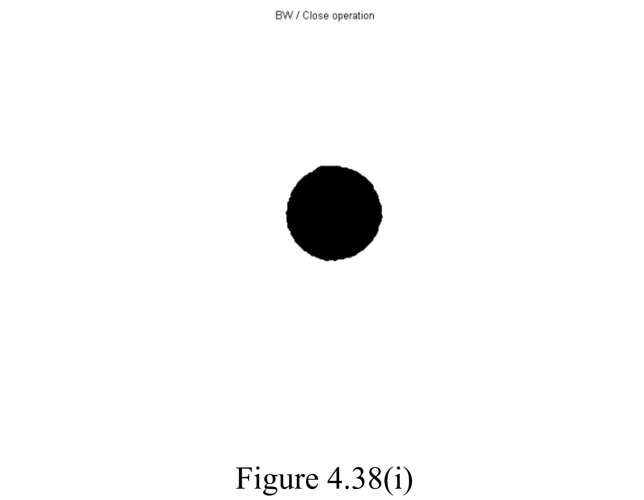


Figure 4.38(i)

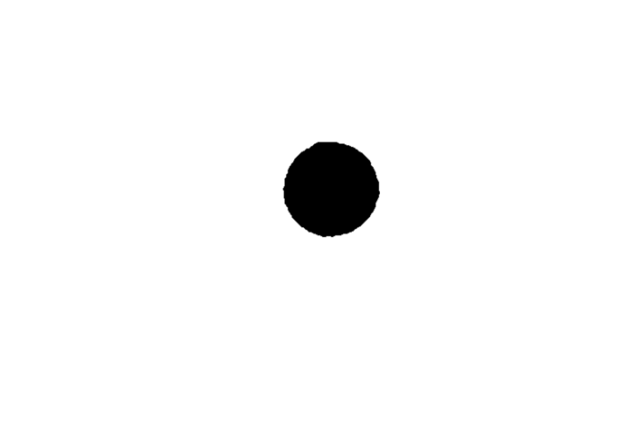


Figure 4.38(j)

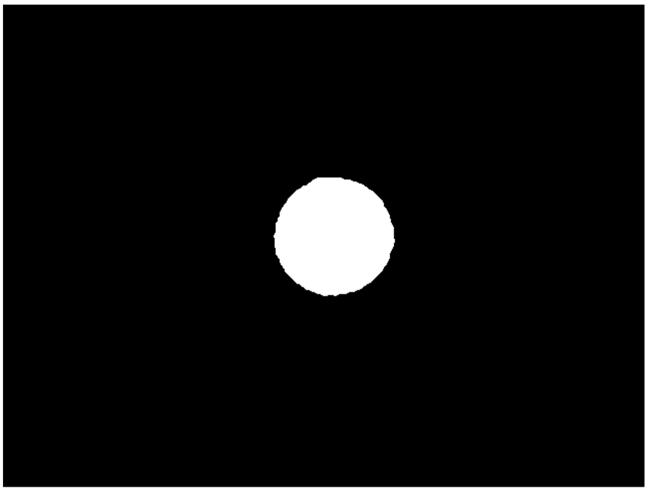


Figure 3.38(k)

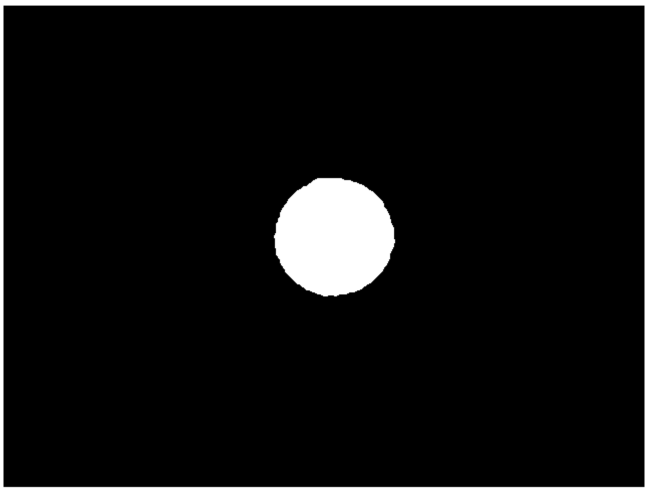


Figure 3.38(l)

Figure 3.38(m) (Area boundary)

Figure 4.38 Images of Morphology Operations Process

Figure 4.39(a) show the melting of the Cheddar samples images taken equal time intervals. After processing the images, time versus area graph is depicted in Figure 4.40. Figure 4.39(b) depicts the melting of the Kashar sample images taken equal time intervals. These images are also processed by the same images processing program to present time versus area graph which is given in Figure 4.41. Figure 4.39(c) shows the melting of the Mozzarella sample image and Figure 4.42 depicts time versus area graph of it.

Note that even though the background color of the Kashar and Mozzarella cheese sample images are abruptly changed, the proposed image processing program eliminates this disturbance and provides good results.

Figure 4.43 shows three cheese time-area curves together

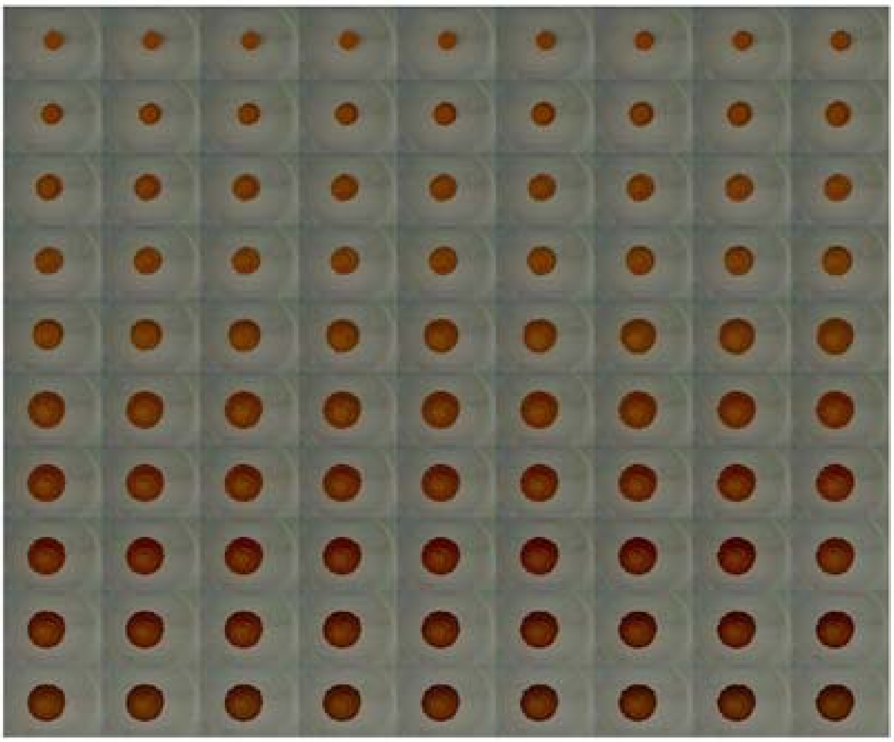


Figure 4.39(a) Cheddar

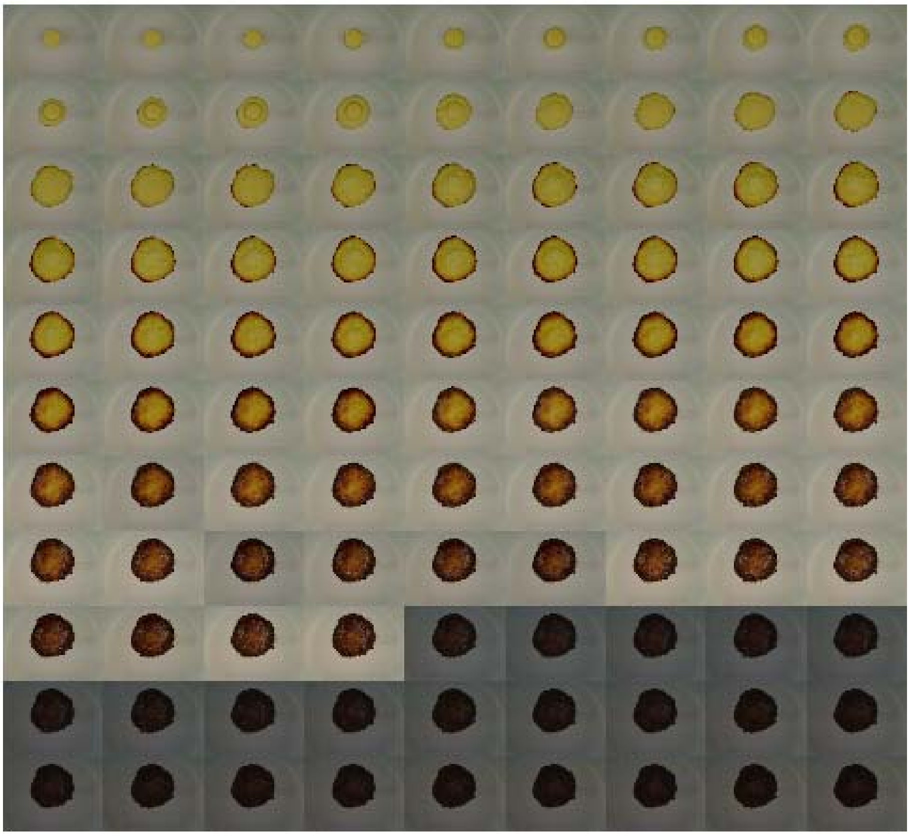


Figure 4.39(b) Kashar

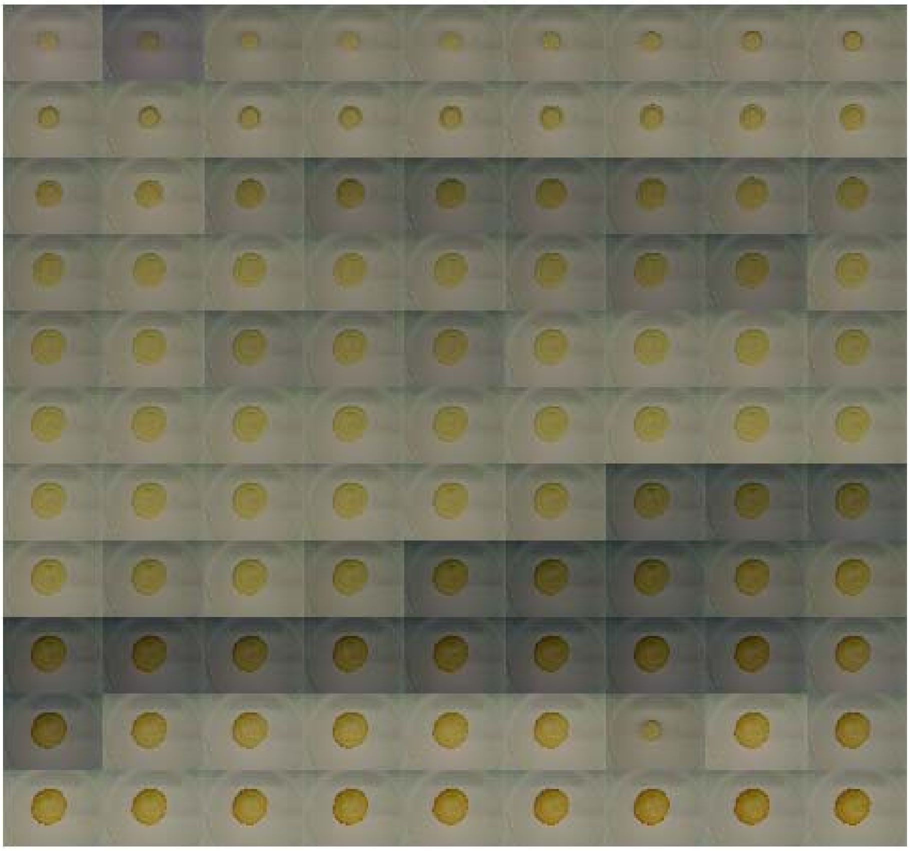


Figure 4.39(c) Mozzarella

Figure 4.39 Images of (a) Cheddar, (b) Kashar, and (c) Mozzarella Cheese within Melting Process

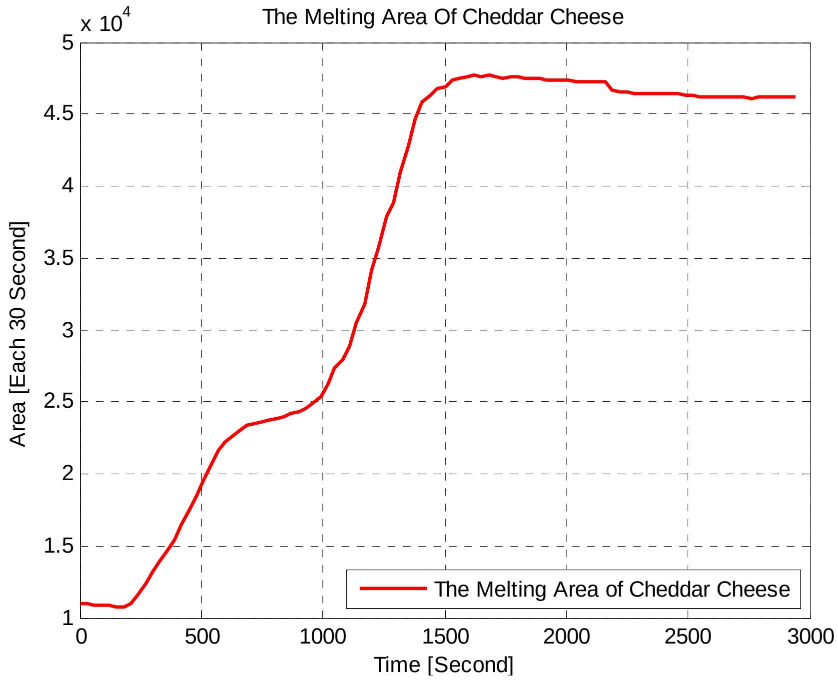


Figure 4.40 The Melting Area of Cheddar Cheese at Temperature 130^o

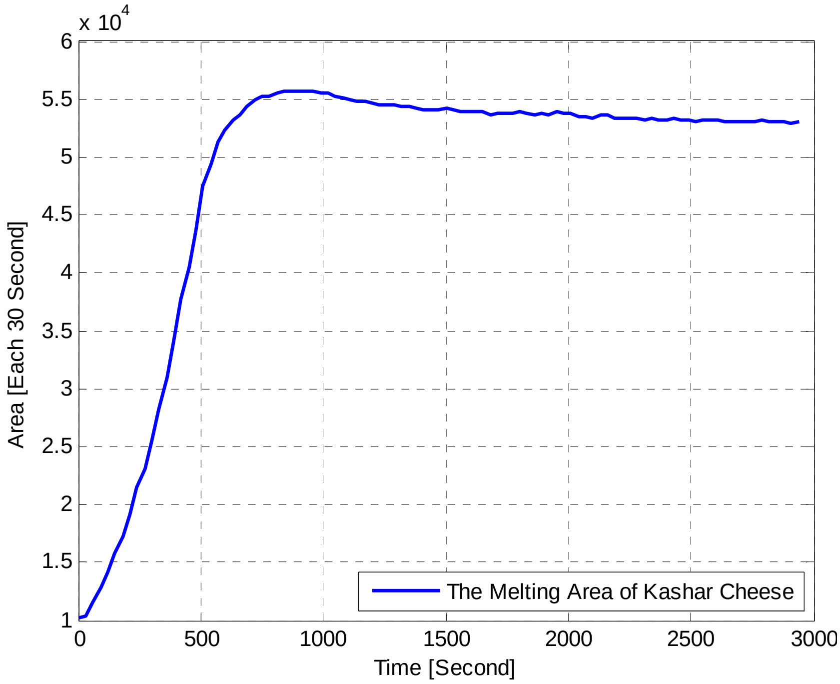


Figure 4.41 The Melting Area of Kashar Cheese at Temperature 130°

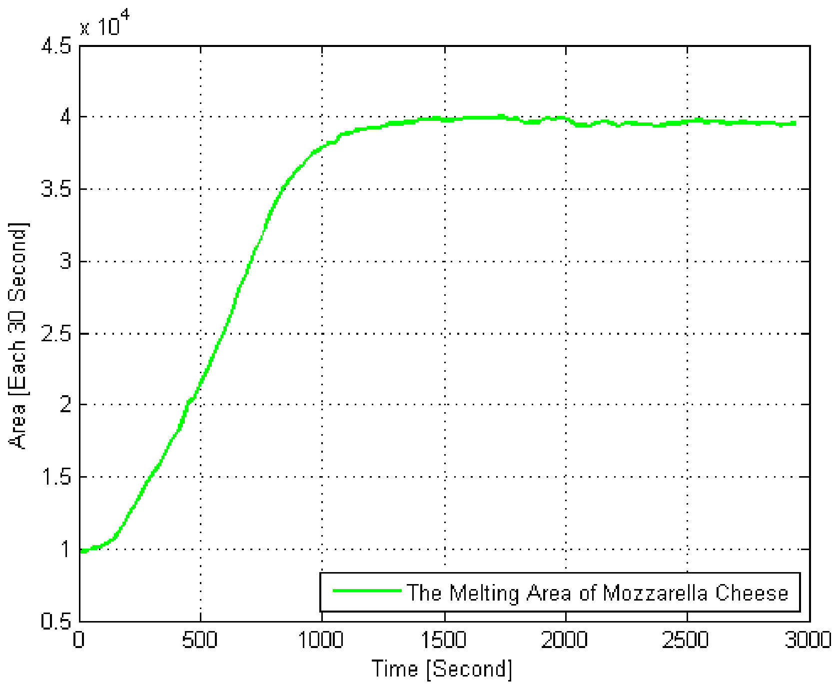


Figure 4.42 The Melting Area of Mozzarella Cheese at Temperature 130°

Determination of Meltability Property:

The ratio of cheese area of the last area of cooking at time t and the initial area before cooking represent the melting degree of the cheese.

Cheddar:

Melting Degree of Cheddar = $\frac{\text{(The Last Area of Cooking at time t)}}{\text{Initial Area before Cooking}}$

Melting Degree of Cheddar = 4.194

While melting rate is the rate of change in melt area during the first minute of cooking.

Melting Rate of Cheddar = $\frac{\text{(The Area after 1 min – Area before Cooking)}}{\text{(Area before Cooking)}} * 100$

Melting Rate of Cheddar =0.833%

Kashar:

Melting Degree of Kashar = $\frac{\text{(The Last Area of Cooking at time t)}}{\text{Initial Area before Cooking}}$

Melting Degree of Kashar = 5.196

Melting Rate of Kashar = $\frac{\text{(The Area after 1 min – Area before Cooking)}}{\text{(Area before Cooking)}} * 100$

Melting Rate of Kashar = 1.962%

Mozzarella:

Melting Degree of Mozzarella = $\frac{\text{(The Last Area of Cooking at time t)}}{\text{Initial Area before Cooking}}$

Melting Degree of Mozzarella = 4.0461

Melting Rate of Mozzarella = $\frac{\text{(The Area after 1 min – Area before Cooking)}}{\text{(Area before Cooking)}} * 100$

Melting Rate of Mozzarella = 0.5297%

Table 4.6 Composition of Cheddar, Kashar, and Mozzarella cheese

Component	Fat (%)
Cheddar	45
Kashar	30
Mozzarella	40

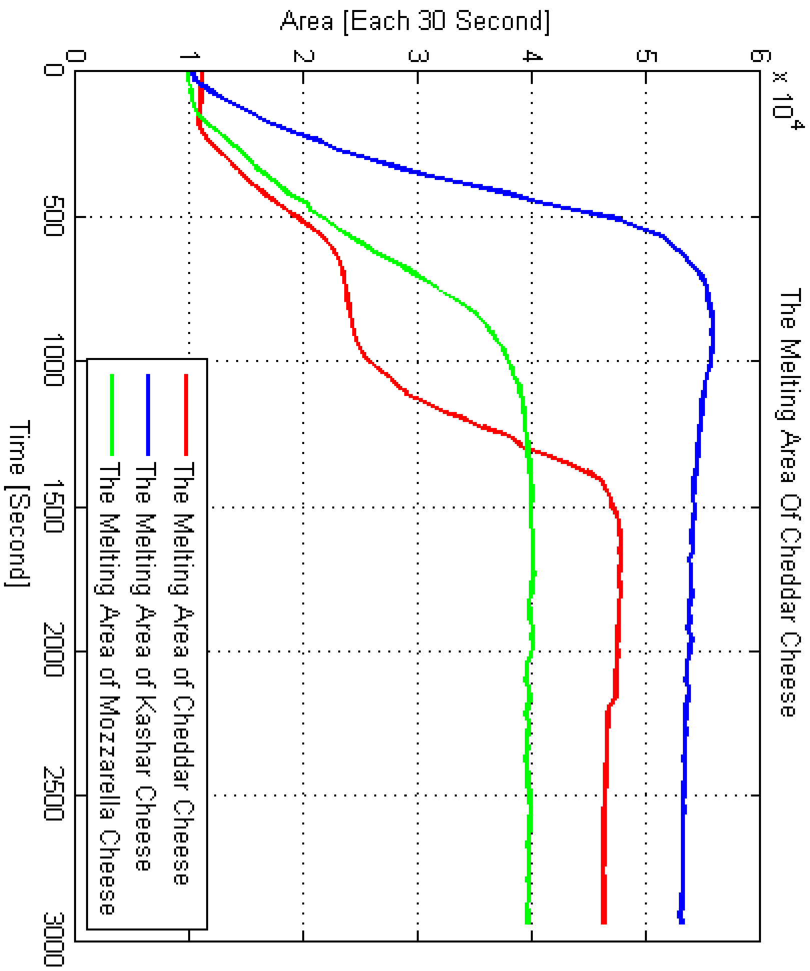


Figure 4.43 The Melting Area of Cheddar, Kashar, and Mozzarella Cheeses at Temperature 130^{o}

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusions and Discussion for the Present Work

Within establishment and implementation of a complete algorithm for image analysis, some of important points are figure out. The algorithm is constructed to find a clear image for object and its area calculation. Through the procedure, passing in the selecting machine tools, construction a device, enhancement, segmentation, calibration, and objective process, some parameters have a crucial effect to draw the oriented of the process, and the result, those aspects includes:

- The quality of the camera.
- The environment where the pictures are taken.
- The color of the tray.
- Analysis of image helps to draw the next step of the process.
- The effectiveness of c parameter in the LOG enhancement technique.
- Standard deviation values for color segmentation method.
- The efficiency of the algorithm.
- The best thresholding value for histogram operation.
- The device is cheaper, faster, and easy to use than currently used device.

<u>The quality of the camera:</u>

The quality of camera is one of the significant components in building an inspection device to avoid signal noises. However, some noise will be appeared and caused a vague of image information. Despite of all the signal noise, camera used is cheap and suitable to get an acceptable image for object.

<u>The environment where the pictures are taken:</u>

Environment is a crucial part of complement the quality of the camera. Terms illumination, light reflection, and shadow are the key factors to distort images information.

The color of the tray:

The color of tray is influence on the object color as shown in Section 3.8. Also every color as shown in Table 3.5 has different frequency. So, the color of the tray has to be a color includes all frequencies (white color).

Analysis of image helps to draw the next step of the process:

In order to construct an algorithm, examination each step is so positive to anticipant the procedure features. This concept was the fundamental key to start and assemble the stages of the process. Plotting RGB colors, histogram, indexed and observing the image channels separately was so effectively to put and expect the complement step, where each key has a special spot from the image that clear the way for choosing the following step as mentioned in Section 4.2. Plotting RGB colormap give an indication about:

- The colormap distribution with its intensity value.
- The progressively of the intensity form highest value to the lowest value.
- The darkness and lightness of the image by observing the high intensity value.
- See the effect process on the image colors range, if it is in compression or extension.
- The highest channel shares the huge amount of the illumination of the whole image.

To illustrate, the Figure 4.2 shows that the object is close to red, more than green and blue consecutively. Furthermore, the distribution of the channels values indicates which channel can be more suitable to extract the object. Besides, it gives an impression about the process effectuation, where if the color are in compression or extension, as displayed in Figures 4.2 and 4.9 after LOG enhancement. Draw a histogram diagram provide an idea about

- The valley value which is measure of the suitability for extraction of the object from the image.
- The noise amount at that value.

As an illustration, Figures 4.3 and Table 4.1 show the histogram and its value result of sample image. Where, it’s shown the noise at thresholding values. Sketches indexed image yield good idea about:

- The influence of the step on smoothing image, and removing or decreasing the light reflection, shadow, and noise.

Finally, observation the RGB channels:

- Discern the noise, and share the amount of it for every channel in the original.

As a result, each step can show the effectiveness of the process and lead the programmer to select the suitable tool for the next level.

<u>The effectiveness of c parameter in the LOG enhancement technique</u>:

Within the algorithm, contrast enhancement by LOG method was the starting point in order to improve the illumination of the image. This step has a special characteristics c which determines the effectiveness of the enhancement. As mentioned in Section 4.31, if the c is higher than one, image will be whiter, and if c is less than one will be darker. The value of c depends on the illumination of the image, if luminous lightly the value will be choice smaller than 1, but if the image is dark will be higher than 1. However, the increasing or decreasing of c diminishes the noise, shadow, and light reflection in the image.

<u>Standard deviation values for color segmentation method</u>:

Standard deviation is one of crucial elements in the color segmentation process which changed from picture to picture. To definition this concept, let take 5 different values [2, 3, 5, 7, 8], then compute the mean value for them (2+3+5+7+8) / 5 = 5. Now, subtract each value from this value and square it. After that, sum of all result value and get the square root, then divided it by the number of the elements. The result will be 1.0198 which is standard deviation value. Figures (5.1 – 5.3) show the behavior of the standard deviation for Cheddar, Kashar, and Mozzarella.

Figure 5.1, Figure 5.2 and Figure 5.3, standard deviation of the original image try to be between the two top channels. From study the manner acting of the standard deviation can be seen in the opposite of thresholding behavior, as shown in the Figures 5.4, Figure 5.5 and Figure 5.6.

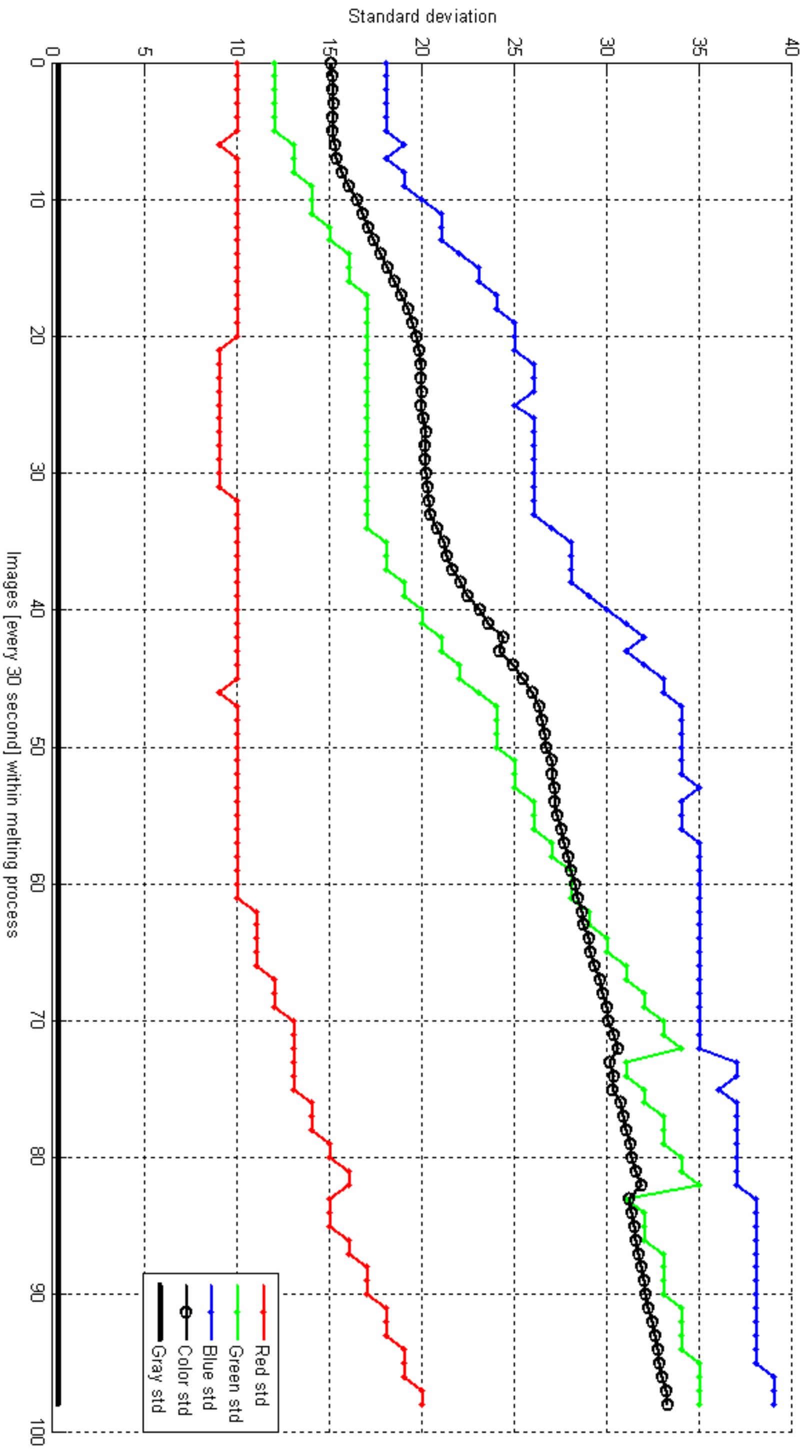


Figure 5.1 Distribution of Standard Deviation Values of Red, Green, Blue, Gray, and Color Images within Growing Process / Cheddar

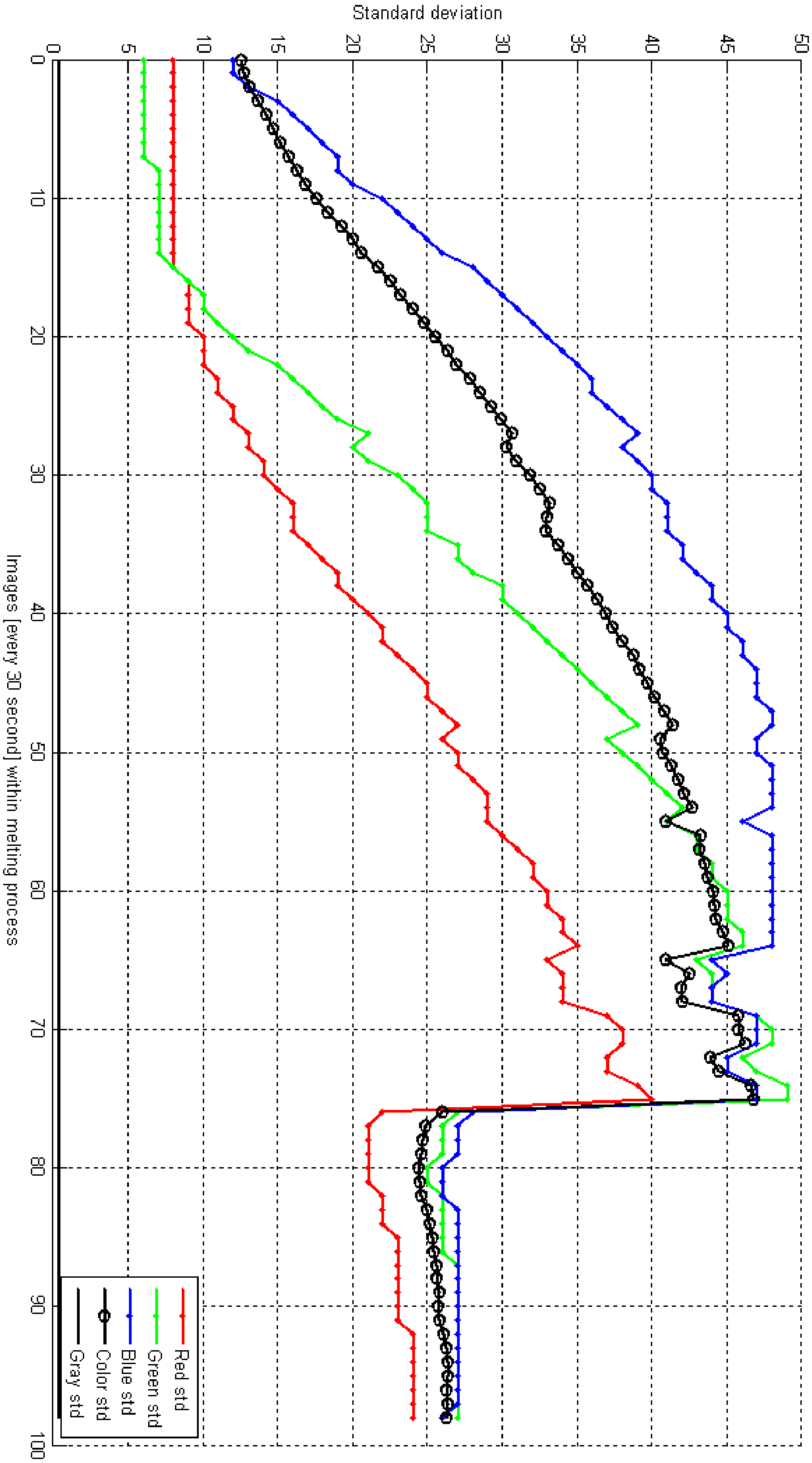


Figure 5.2 Distribution of Standard Deviation Values of Red, Green, Blue, Gray, and Color Images within Growing Process / Kashar

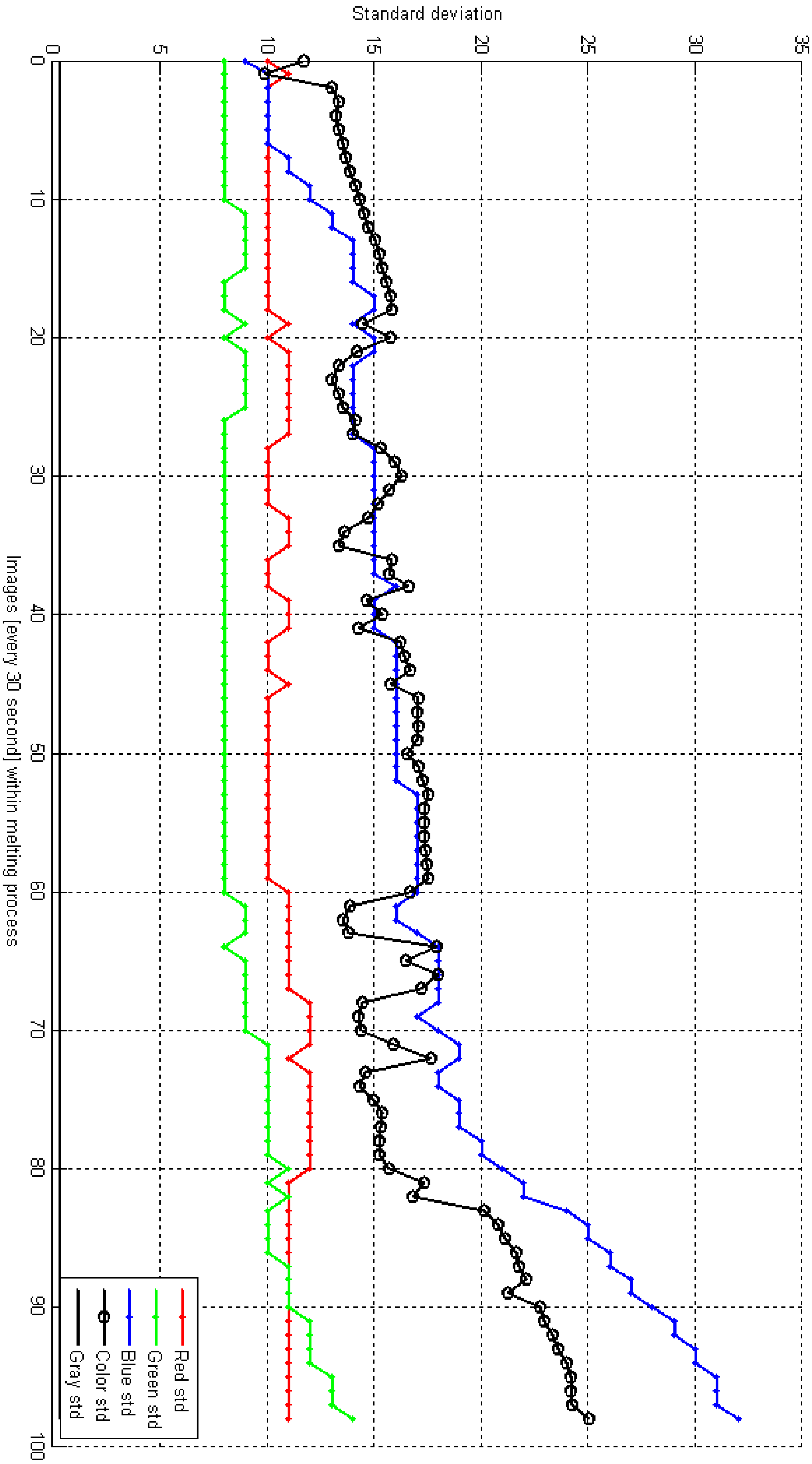


Figure 5.3 Distribution of Standard Deviation Values of Red, Green, Blue, Gray, and Color Images within Growing Process / Mozzarella

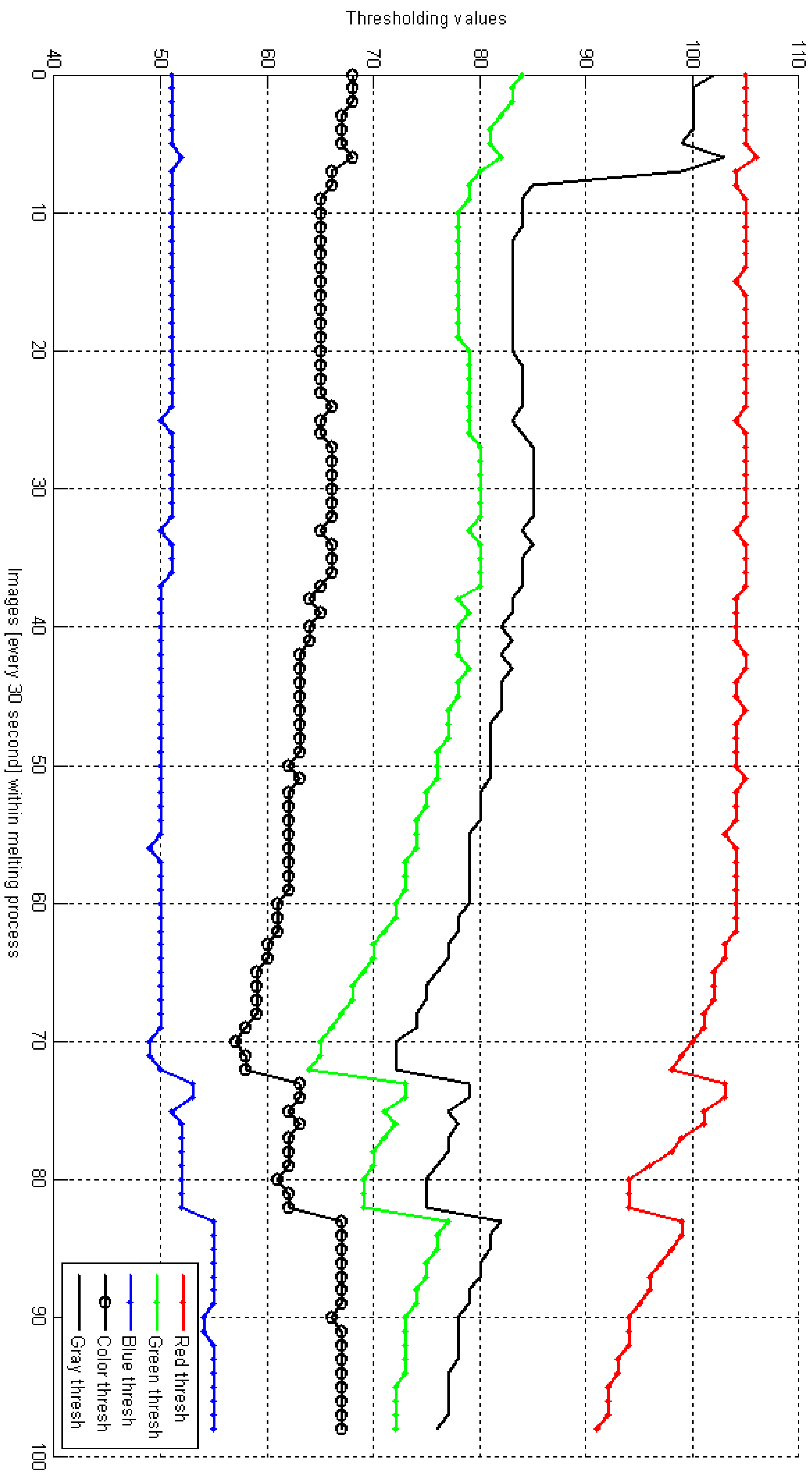


Figure 5.4 Distribution of Thresholding Values of Red, Green, Blue, Gray, and Color Images within Growing Process / Cheddar

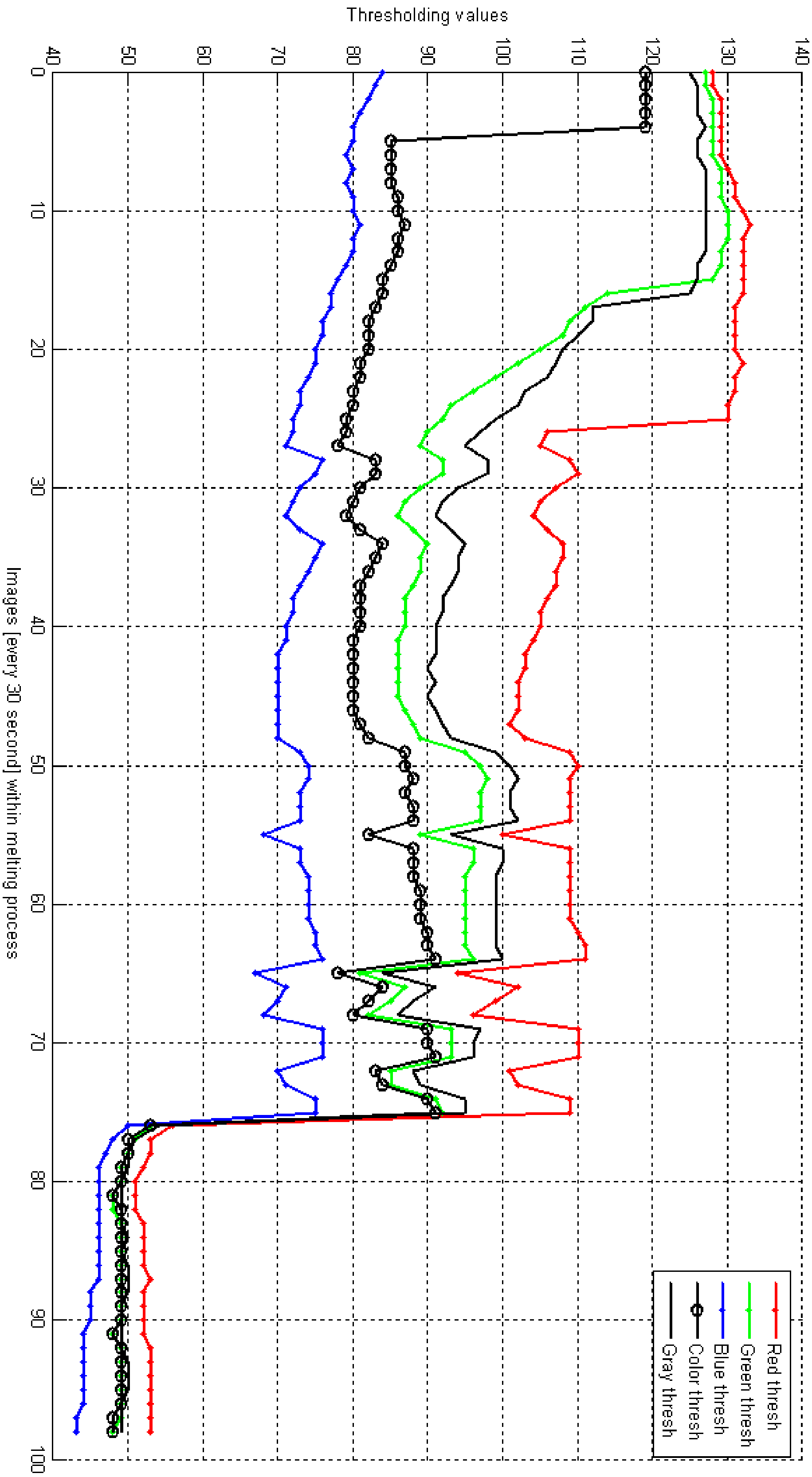


Figure 5.5 Distribution of Thresholding Values of Red, Green, Blue, Gray, and Color Images within Growing Process / Kashar

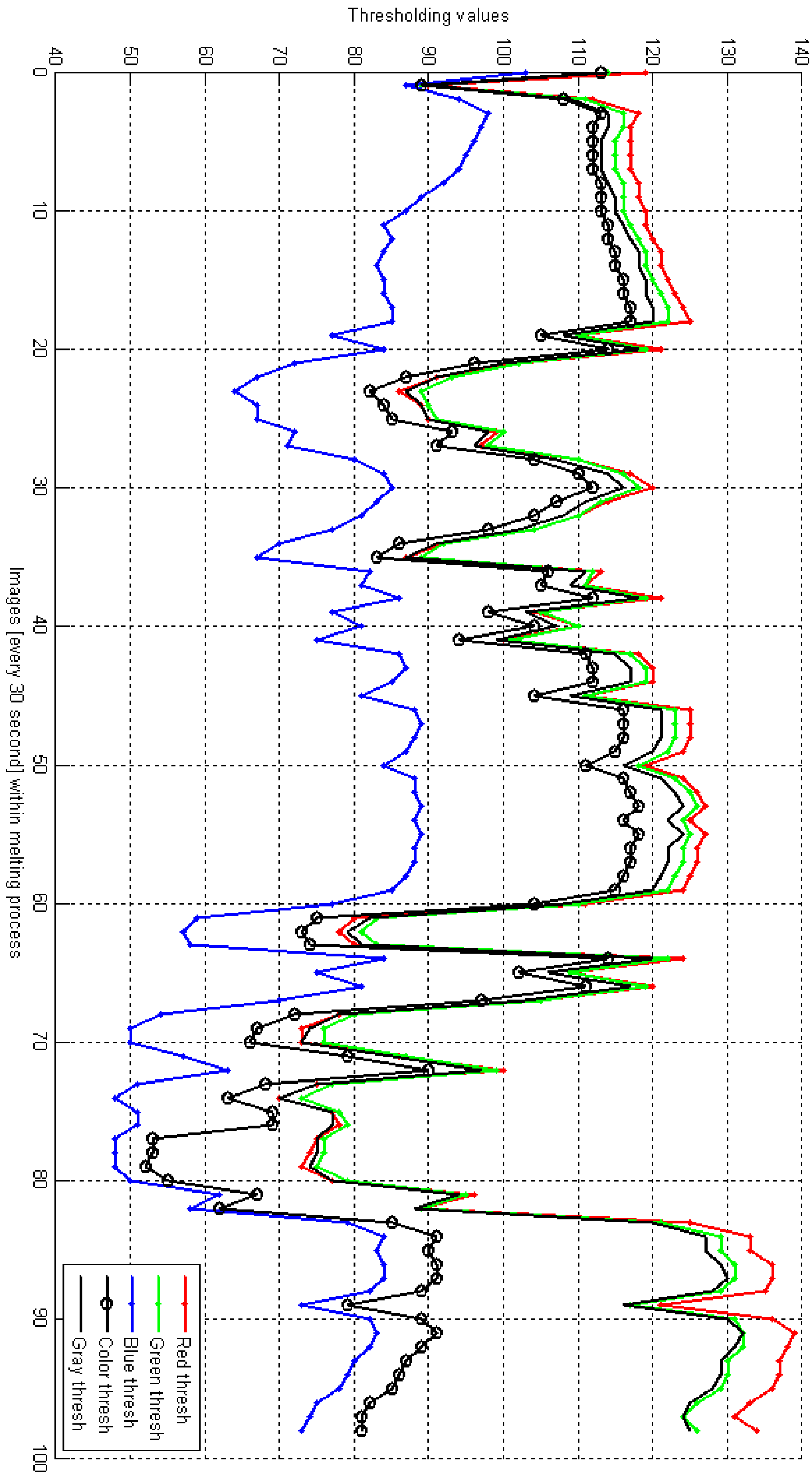


Figure 5.6 Distribution of Thresholding Values of Red, Green, Blue, Gray, and Color Images within Growing Process / Mozzarella

The efficiency of the algorithm:

The algorithm for extracting area ranging from perfect (cheddar) to the accept result (Mozzarella). Figure 4.43 shows the area growing, where it can be can see that the line has a little amount of oscillation, since the clarity of the object's edge is not perfect. This happened because the color of the cheese embedded in the background color, add to that noise, shadow, and light reflection.

The best thresholding value for histogram operation:

Generally, from the Figure 5.4, Figure 5.5, and Figure 5.6 color thresholding values are restricted between the two bottoms channels and near almost from the top rather than down. While the gray thresholding surrounded by the top and middle channels and near from the middle channel rather than top. It is concluded that the best thresholding value is enclosed between the color and gray thresholding values. Lastly, its worthy to mention almost the picture have two near channel values and almost linear, like the red and green channels of Mozzarella, difficult to separate the object from background. Within my study, I found out that the best thresholding value is the summation of R, G, and B channels thresholding separately over 3, where it will be restrict between gray and color value. As shown in Figure 5.7, Figure 5.8, and Figure 5.9:

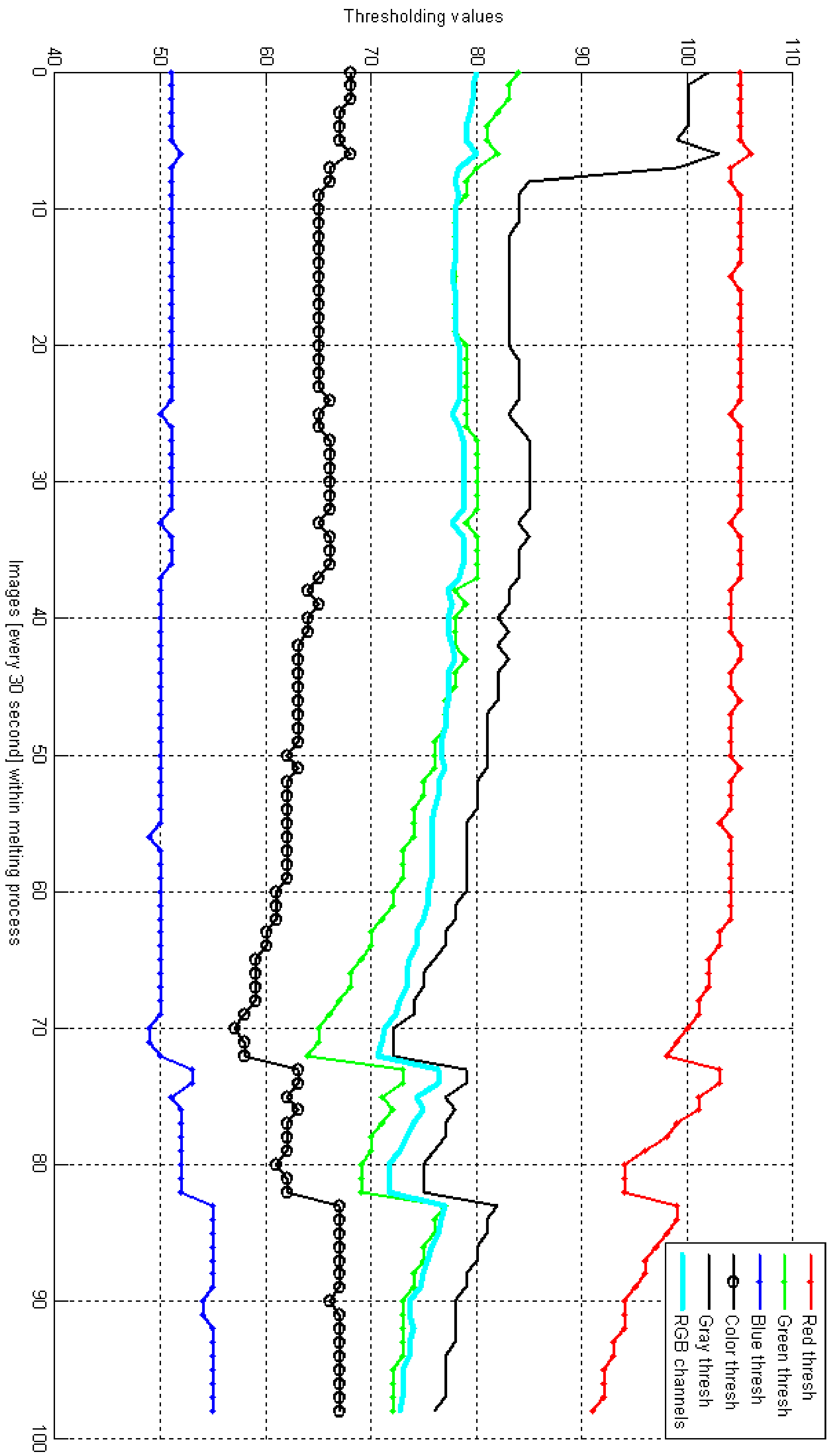


Figure 5.7 Distribution 0f Thresholding Values of Red, Green, Blue, Gray, Color, and Summation of RGB Images within Growing Process / Cheddar

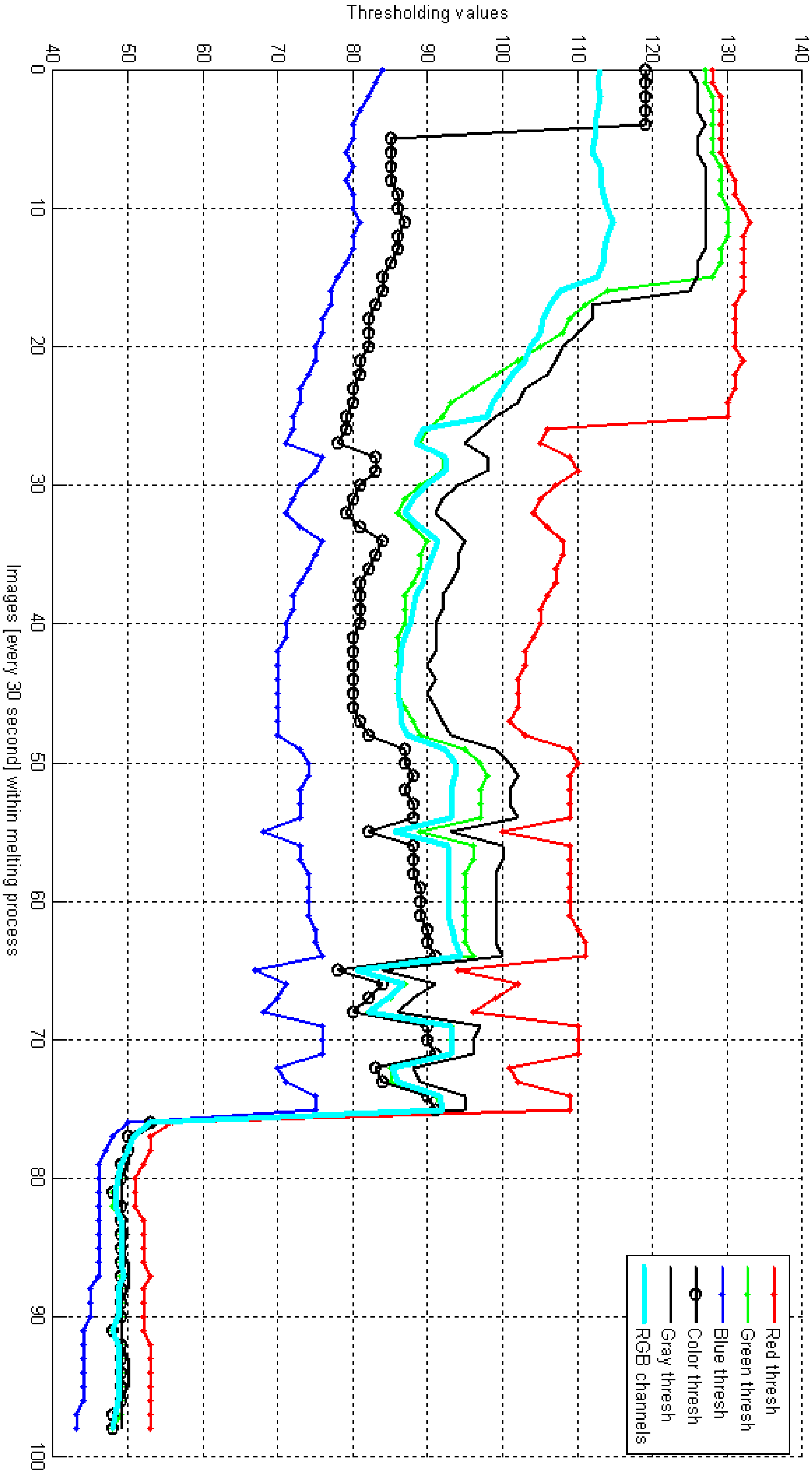


Figure 5.8 Distribution of Thresholding Values of Red, Green, Blue, Gray, Color, and Summation of RGB Images within Growing Process / Kashar

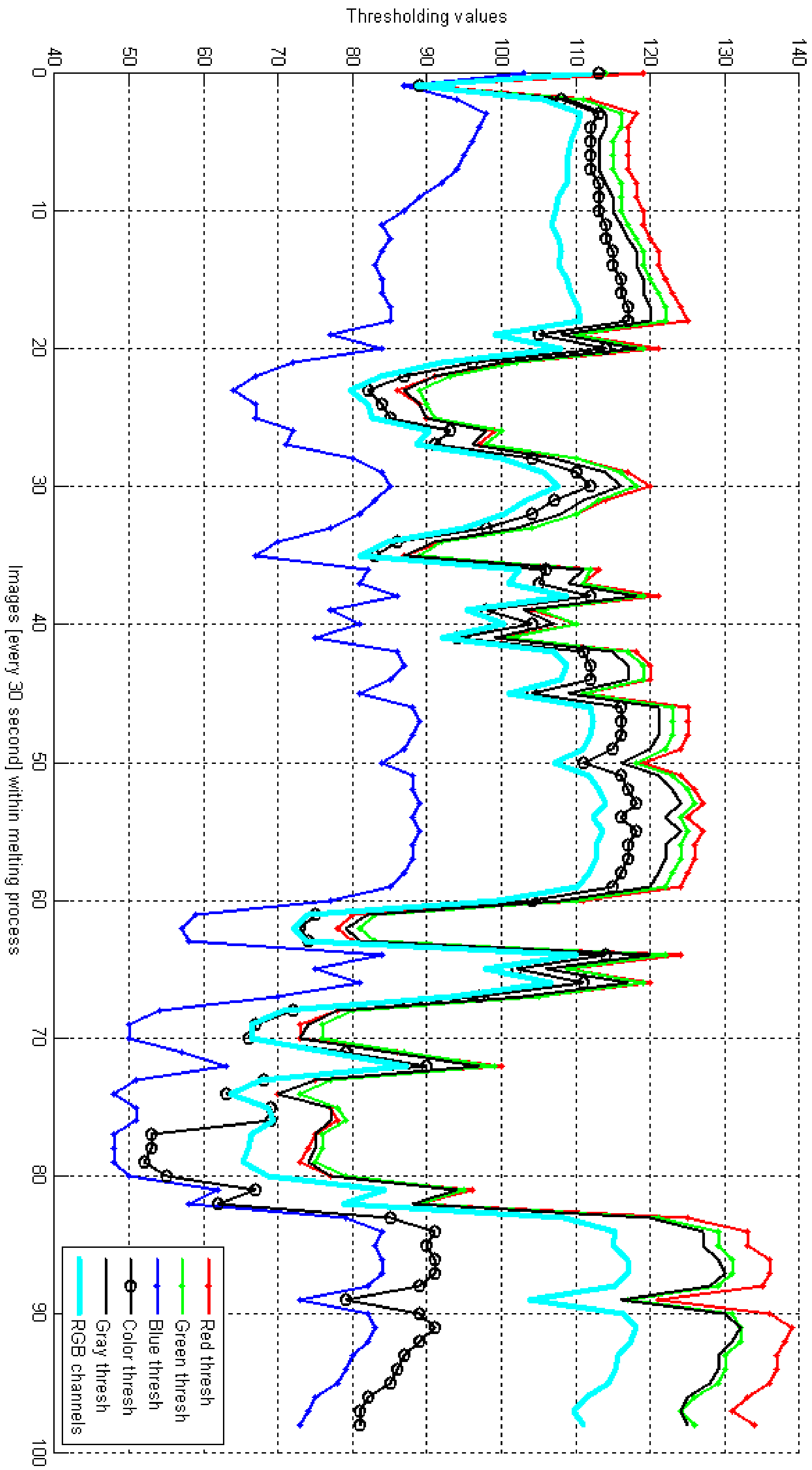


Figure 5.9 Distribution of Thresholding Values of Red, Green, Blue, Gray, Color, and Summation of RGB Images within Growing Process / Mozzarella

5.2 Future Works

Through the study of the results several questions are appeared about the possibility of developing the device and its ability. Several proposals are put forward in the form of ideas those include:

- Use the second camera for clearing the image shape, and prove the objective operation of the image.

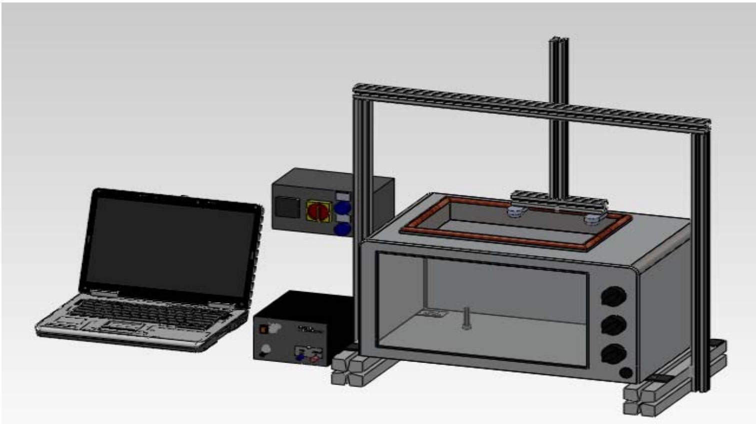


Figure 5.10 Schematics of the Inspection Device with the Stereo Vision System

- Use two light lasers from two sides apply directly to the cheese can clear the object and decrease the noise, environment reflection, and shadow.

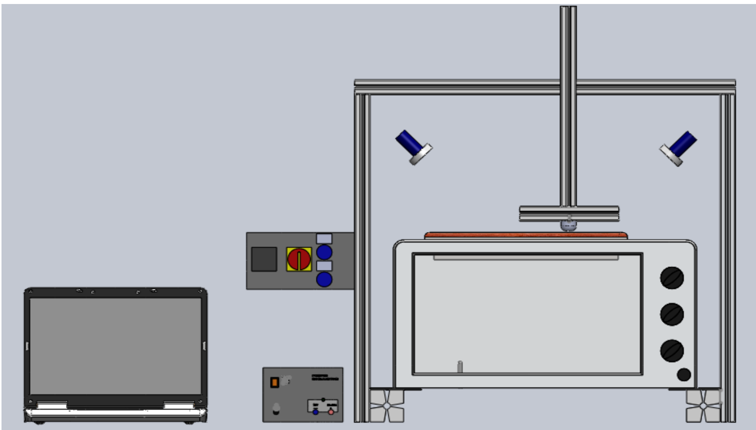


Figure 5.11 Schematics of the Inspection Device with the Laser System

- Adding a sensor may increase ability to measure the edge, height, smoothing of the object, and help to improve the images information. Theoretically, the sensor sends the signals to the MATLAB, where it compares with the image data taken in the same time. After that, the signals correct the image data and remove the noise, reflection and shadow. Typically, many cheap sensors can perfectly do this duty like ultrasonic.

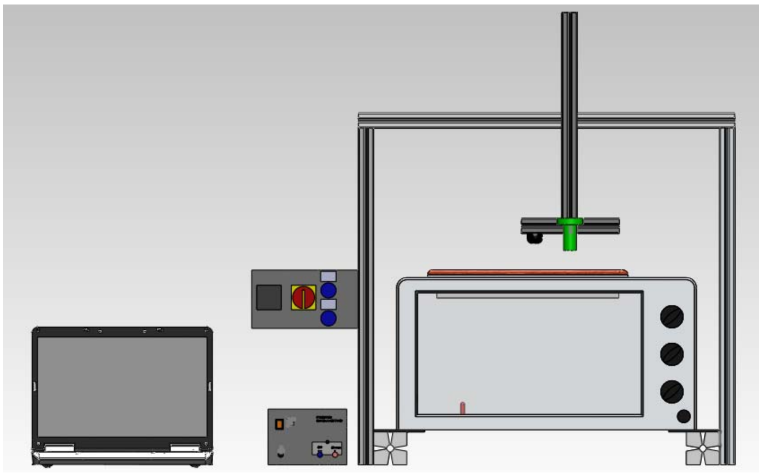


Figure 5.12 Schematics of the Inspection Device with the Sensor System

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