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ANALYZING THE EFFECT OF POLARIZATION IN IMAGING

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ELECTRICAL & ELECTRONICS ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

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ANALYSING THE EFFECT OF POLARIZATION IN IMAGING

By

INDRATNO PARDIANSYAH

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
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CERTIFICATION OF APPROVAL

ANALYZING THE EFFECT OF POLARIZATION IN IMAGING

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A project dissertation submitted to the
Department of Electrical & Electronic Engineering
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(Electrical & Electronic Engineering)

Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Indratno Pardiansyah

ABSTRACT

Light as the natural element for our life can be characterized by its intensity, wavelength and polarization. The polarization is general characteristic of wave (light, gravitational wave, sound wave etc.) that have the information of their oscillations as well as the reflecting object. Polarization of light could not be viewed naturally by our naked human eyes due to the limitation of capabilities of capturing light on a muscle known as the ciliary muscle. Nowadays, in the computer vision, the polarization is used to determine image segmentation, object and texture recognition. Moreover, in the medical field, polarization is used to allow better the diagnose of skin texture and lesion. This project uses digital image processing technique to analyze the effect of polarization in imaging, which focuses on identifying the textures or patterns of an object. In the polarization on human skin's imaging, this analysis technique is developed to classify and determine the texture of human skin based on the different races background with the aid of polarized light as well to distinguish between the texture of normal skin and skin lesion.

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CHAPTER 1

INTRODUCTION

1.1 Background

Polarization is general characteristic of waves (light, gravitational wave, sound wave, etc.) that have the information of their oscillations. Light can be described as the electromagnetic wave consists of mutually perpendicular, fluctuating electric and magnetic field which travel through the vacuum of outer space and visible to the human eye. The magnetic and electric field vectors of light are orthogonal to the direction of light and orthogonal each other. Then it will cause the field of vectors are oscillating and causing in a change of vector with time and space (Born & Wolf, 1999). When the light (the unpolarized light) hits onto surface, either metallic or non-metallic surface, it will be linearly polarized. Therefore, in other words, the polarization can be defined as the process of transformation of the unpolarized light into the polarized light.

The unpolarized light could be transformed into polarized light by several methods. There are at least four methods to transform the unpolarized light into polarized light.

1. Polarization by transmission
2. Polarization by refraction
3. Polarization by reflection
4. Polarization by scattering

When the light reflected from a non-metallic surface, it would be polarized. Afterwards, the electric wave of light might be focused on single direction or it might change direction in rotary as the wave movements. Therefore, at least there are three types of polarized light.

1. Linear polarization
2. Circular polarization
3. Elliptical polarization

Our eyes have no capabilities to sense or use the polarization due to the limitation of capabilities on a muscle known as the ciliary muscle. However, for most of insects and other vertebrate animals, their retinas are very sensitive to this property of light. They use this phenomenon for their navigation to find the direction or to prevent them from their predator. Even though our human eyes are unable to sense this phenomenon, but back on the history of science, there were some investigations of polarized light have been discovered even for almost half centuries ago.

In the science history, the earliest investigation of polarized light was discovered by Erasmus Bartolinus in 1669 with the phenomenon of double refraction of light in calcite crystal through an Iceland spar (Coulson, 1984). Then, followed by Christian Huygens; extinguishing the two rays arising from refraction of calcite. The British professor Thomas Young in 1802 proved the wave theory of light and in 1807 he developed the theory of color vision known as Young-Helmholtz theory (Wood, 2011). An officer in French army, Etienne-Louis Malus in 1808 has discovered the reflection of light from a non-metallic surface produce partial polarization (Pelosi, 2009). In 1812, Sir David Brewster developed an experiment to investigate the behavior of reflection light from the glass and he also discovered the theory of Brewster’s angle (Lakhtakia, 1989). James Clerk Maxwell then completes the investigation of polarization light by discovering the electromagnetic theory in 1864 (Griffiths, 1999).

Nowadays polarization is generally used almost in all fields of science. Polarization is used to analyze the reflection of light, to analyze solar and atmospheric phenomenon, to analyze the effect of polarization for most insects and certain vertebrate animals, to identify or classify materials and minerals, to identify the chemical reaction, bond and isomer, for communication and radar applications, and currently the polarization is used as well in the medical field.

In the medical field, polarization of light is not a new method. It has been used since the invention of X-ray by Rontgen. Nowadays polarization of light can be used to get the image of the tissue layer of skin to diagnose a skin disease or lesion, for example a skin cancer. By using this method allow a doctor to observe the difference color or texture on the surficial layers of skin to diagnose the margins of cancer visually.

Thus, the polarization of light has been used as a necessary measurement tool to study of the phenomenon that occurs in our environment. Therefore, this proposal present the various methods of analyzing effect of polarization especially in imaging of skin for the medical purpose and the imaging of scenery in photography.

1.2 Problem Statement

The light which is produced by the sun, by the lamp as well by a candle flame is mostly unpolarized light. The unpolarized light occurs when the electric charges of light (light is an electromagnetic wave) vibrates in several of direction and creating the light waves. The unpolarized light is made up of the components of polarized light in whole perpendicular directions to the propagation direction of the light.

The reflected light sometimes can cause bad visualization on imaging. For instance, when we are taking picture of sky or scenery, without using a polarizer, the result of the picture would look not so clear different than by using a polarizer. It is caused by the amount of reflected light (known as artifact) that captured by the cameras lens is too much. However, when we are using a polarizer filter, the reflected light will be reduced and blocked so that the result of the picture will be more visible. The Figure 1 below showed the different picture that taken without polarizer and by using polarizer.

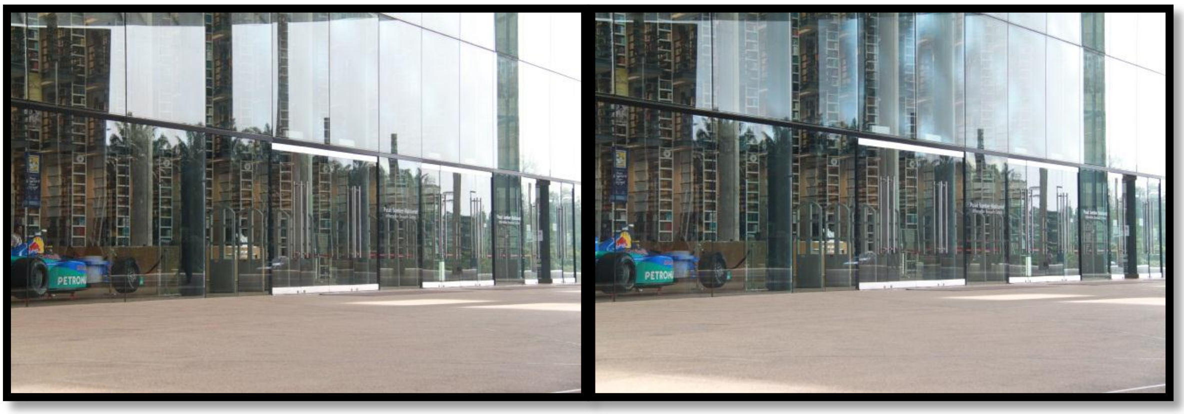


Figure 1 : Picture without polarizer (Left), picture with polarizer (right)

The polarization actually can be used to identify or to recognize the texture or pattern of an object. In the computer vision, material classification is an essential task to be performed, where it provides the essential important information for scene understanding (Chen & Wolff, 1999).

An incident unpolarized which becomes partially polarized can cause the difficulty vision on material classification or object recognition due to the reflection of light. For instance, the determination and verification of the metals and insulator part placements is required to overcome problem in a circuit board design. This problem can be observed by taking the image sample of the circuit board design and analyze it by using the image processing technique to observe the polarization's effect on the texture of the metal and insulator part of the circuit board image.

In medical field, skin disease or lesion often occurs in the superficial tissue layer of the epidermis and then spread into the superficial tissue layers of the papillary dermis. In the examining the symptom of a skin disease, it is needed a preliminary analysis and examination based on color and texture of skin to diagnose a skin disease or lesion. Some skin lesions can easily be observed by our own eyes, but some others might be difficult to be observed. Therefore, the analysis on the texture image of skin is required to obtain better advance in analysis. Hence, by the aid of the polarized light, the image contrast will be concerned on the tissue layers where the skin diseases or lesions arise and can be easily identity the texture of the skin lesions.

An image actually can be analyzed based on its characteristics, such as edge, texture, pattern and other image features by using image processing technique. The most interesting part to be analyzed in the image of an object is the texture or the pattern which made the object.

Why is this project focus on texture features? The texture is actually the variation of data at scales smaller than the scales of interest. Therefore, by focusing on the texture image, we can recognize or identify an object from its shape as well as from the material that made it. The texture can also give the important cue in object recognition, i.e. the material which made the object. The texture may also be a nuisance in an automatic vision system so that it will give confusion on the shape recognition algorithm.

At last, the effect of polarization of light has a lot of advantages to be explored for our live due to our human eyes have lack of capability to utilize and observe this phenomenon naturally. Therefore, this project will concern on the effect of polarization on imaging which is focus on texture characteristic of imaging. By using the image processing technique, this project will try to solve some problems concerned with texture, such as texture classification.

1.3 Objectives

The project is a study and analysis based which emphasized the effect of polarized light to identify or recognize the texture of an object as well as the texture of human skin. Thus, there are two main objectives of this project:

- To analyze the effect of polarized light to identify or recognize the texture of an object.

- To analyze the effect of polarized light to identify or recognize the texture of the human skin to distinguish between the normal skin texture and the skin lesion texture.

1.4 Scope of Study

This project is generally focused on analyzing effect of polarization in imaging. However, since the project scope of polarization is to wide and could include all of fields in science, therefore this project would be concentrated on analyzing the effect of polarized light that occurs in imaging of skylight and scenery as well as the imaging of human skin.

CHAPTER II

LITERATURE REVIEW & THEORY

2.1 Basic of polarization

Polarization is literally a process to transform the unpolarized light into the polarized light. This polarized light can be described as the light waves in form of vibration that occur in a single plane. The polarization could be classified into three types of polarization, such linear polarization, elliptical polarization and circular polarization.

The linear polarization occurs when an unpolarized light reflect from a surface, it will then be polarized into a single direction of plane. It is because the properties of light which are the electric field and magnetic field will vibrate perpendicular to the propagation direction with one another (Konnen, 1985). The simplest example of this phenomenon is the sunlight. When the sunlight enters into the atmosphere of earth, it will be linearly polarized when it is reflected off of a surface, for example a body of water (lake, river or ocean) or wall. The monophasic and monochromatic light could be described as linear polarization and the light from lasers is one of these examples, when it is polarized.

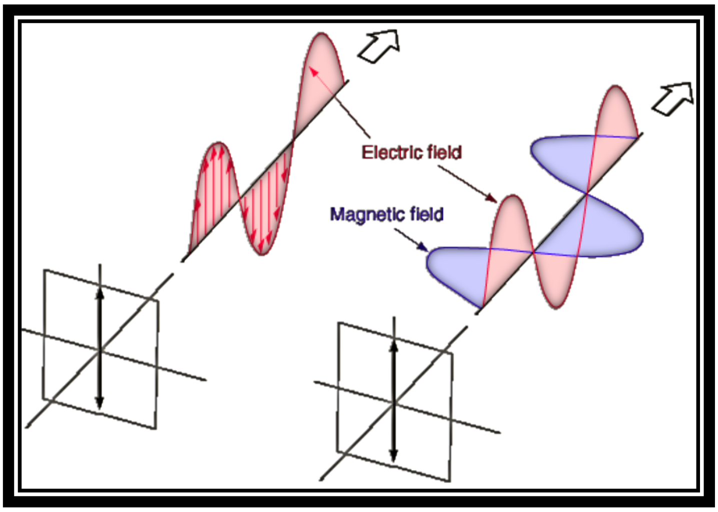


Figure 2 : The scheme of linear polarization [Nave].

Another type of polarization is the circular polarization. This phenomenon occurs when the electromagnetic wave of light forms a direction of spiral and it is not formed by the vibration of direction, otherwise the sense of rotation (Konnen, 1985). The circular polarization could be formed by a combination of two linear polarizations horizontally and vertically with a 90-degree phase shift.

The circular polarization can be divided into two types, those are Right-handed Circularly Polarized Light (RCPL) and Left-handed Circularly Polarized Light (LCPL). The RCPL occurs when the electromagnetic wave of circularly polarized light rotates in a counter-clockwise direction, meanwhile the LCPL occurs when it rotates in a clockwise direction. The circularly polarized light could become linearly polarized light, if it is across through transparent material with a thickness and refractive index that cause light runs slow down (Huei Chiou, et al., 2008).

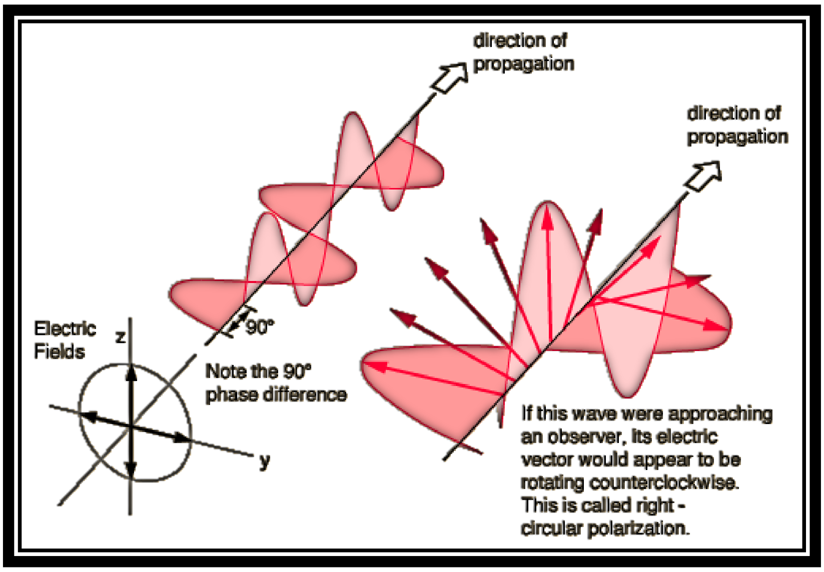


Figure 3 : The scheme of circular polarization (Nave)

Last type of polarization of light is elliptical polarization. The elliptically polarized light occurs when two linearly polarized light waves form two perpendicular wave of unequal amplitude which differs in phase by 90^{o}. It is due to the elliptically polarized light is classified by its direction (as the linearly polarized) and by the rotation motion (as the circularly polarized light), the elliptically polarized light is often described as the combining of two polarized light, which are the linearly and circularly polarized light (Konnen, 1985).

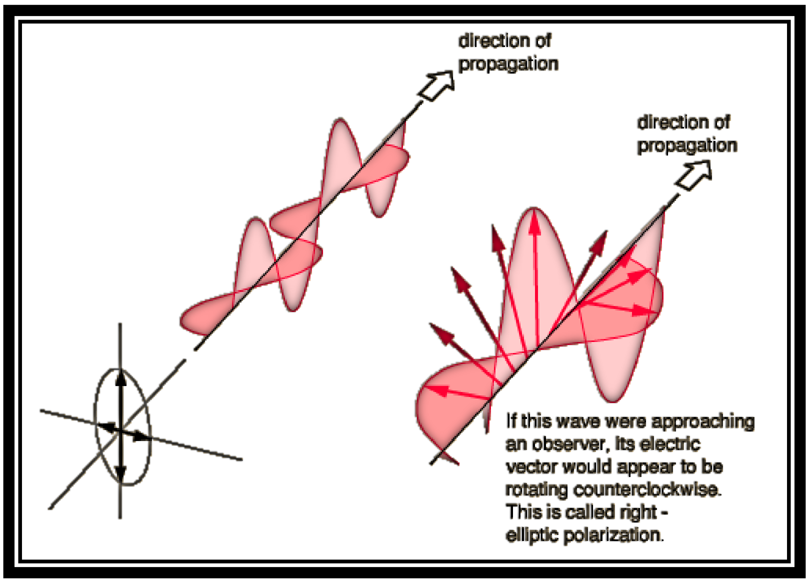


Figure 4 : The scheme of elliptical polarization (Nave).

2.2 Method of Polarization

Unpolarized light wave become a polarized wave could be occurred in three methods of polarization.

2.2.1 Polarization by Reflection

An unpolarized light wave generally becomes partially linearly polarized, after a reflection onto a surface. This phenomenon could occur depend on the angle of the light approaches on the surface as well the material of the surface.

There are two kind of material that can cause the polarization of light, which are metallic and nonmetallic surface. The light will be slightly reflected from the metallic surfaces with variety of vibrational directions, due to the light is an electromagnetic wave and the metals are significantly conducting so that it will absorbs the light and little bit of light will be reflected as unpolarized.

However, the nonmetallic surfaces, for examples asphalt roadways and water surface will reflect the light when there is a large concentration of vibrations in a plane parallel to the surface and generally this phenomenon occurs maximum at Brewster's angle about 56º from the vertical line.

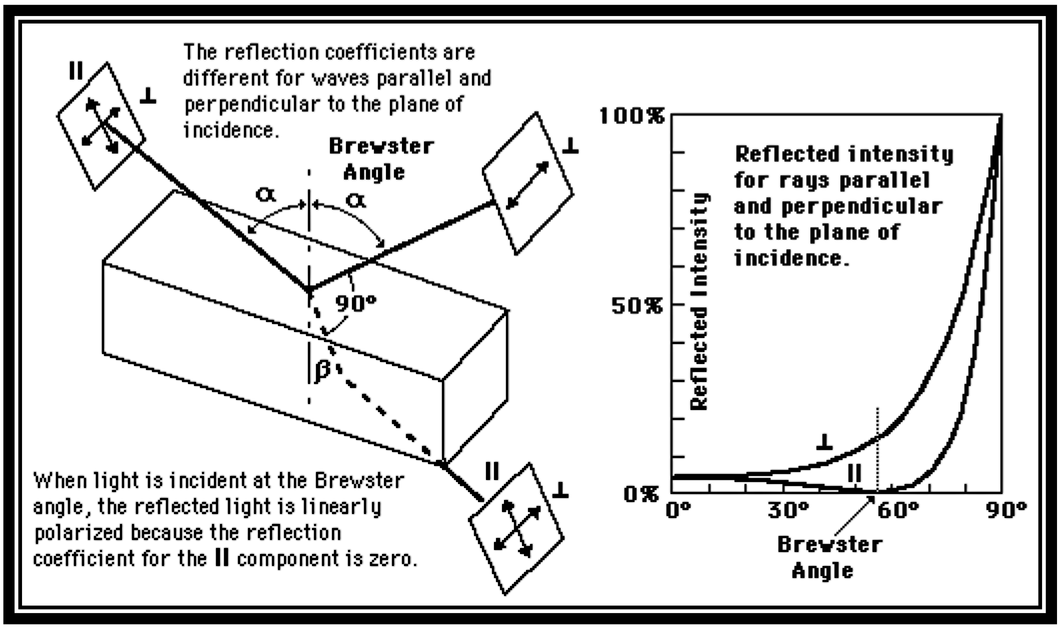


Figure 5 : The Brewster's angle (Nave)**.**

Based on the figure above, the light will be polarized between the angle of 0º and 90º. The angle of which this phenomenon occurs is called the Brewster's angle. However, if the angle of the reflected light is not exactly the Brewster's angle, the reflected light will be partially polarized.

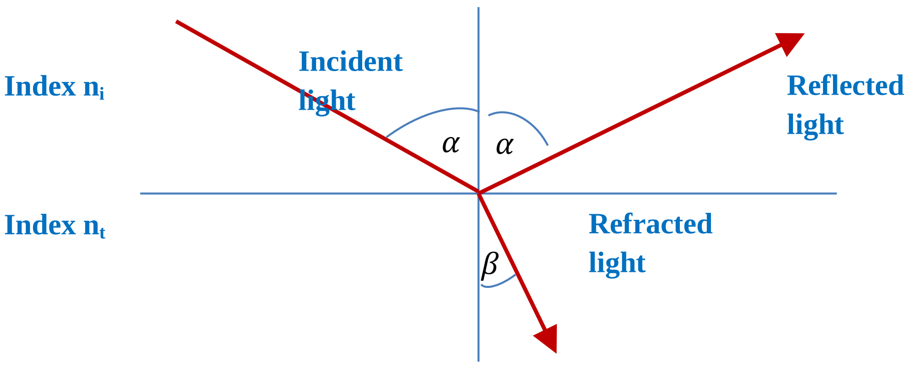


Figure 6 : The concept of polarization by reflection

The Brewster's angle can be determined from the Snell's Law and Fresnel's law. The Fresnel's law determines the reflection and transmission of electromagnetic waves at an interface, while the Snell's law determines the Brewster's angle by using the incident and transmitted angles of Fresnel's Law.

$$r_{||} = \frac{\tan(\alpha - \beta)}{\tan(\alpha + \beta)} = 0$$

When $\alpha + \beta = 90°$, then $n_i \sin\alpha = n_t \sin(90° - \alpha)$. By using the Snell's law then the Brewster's angel can be determined.

$$\tan\alpha = \frac{n_t}{n_i}$$

2.2.2 Polarization by Refraction

The polarization of light could occur as well by refraction. Refraction will occur when the wave of light passes from one material into another material, for instance when the light from the air passes to the water, the unpolarized sunlight will be partially linearly polarized. The partially polarized that occur under water is mostly linearly with some ellipticity beyond the edge of Snell's window (Horvath & Varju, 1995). The Snell's window is a phenomenon of underwater vision from a viewer when looking to the world above the water, he might see an arc or a cone of light above the water surface (Edge & Turner, 2001).

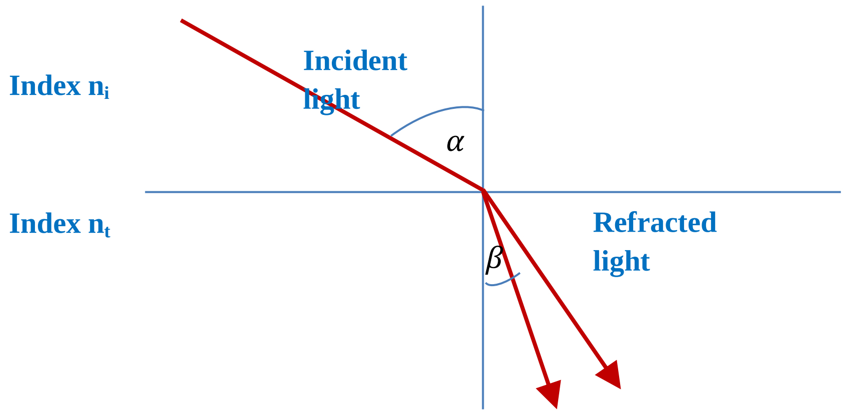


Figure 7 : The concept of polarization by refraction

There are two different underwater polarization patterns, refraction-polarization pattern (RPP) of skylight and the bulk transmission polarization pattern (BTPP). The refraction-polarization pattern occurs within the Snell's window, but it is reformed due to the refraction and repolarization of light at the interface of air and water. Meanwhile, the bulk transmission-polarization pattern occurs outside the Snell's window and caused by the interaction of water and light transmitted (Horvath & Varju, 1995).

2.2.3 Polarization by Scattering

The scattered polarization occurs when the light is scattered while passing into a medium. The light strikes the atoms of a material and it will convert the electrons into vibration. The vibrating electrons then create the electromagnetic wave that will be polarized outward in all directions.

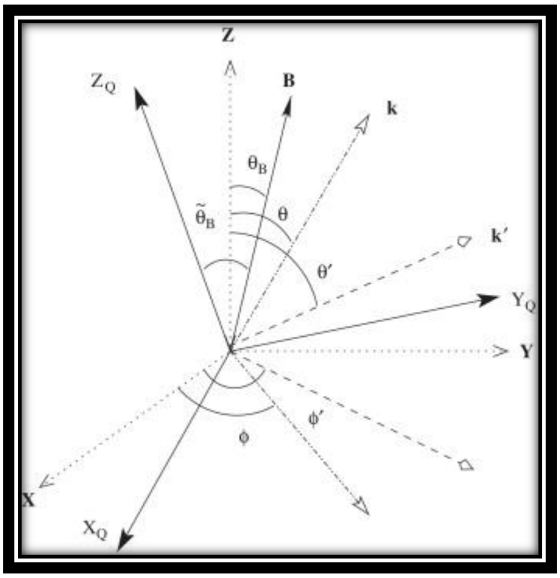


Figure 8 : The concept of polarization by scattering

The scattered polarization could be observed as the light passes the earth's atmosphere. This phenomenon has contributed to the blueness of the sky and the redness of the sky when sunrise and sunset.

2.3 Degree of Polarization

The degree of polarization is a quantity to determine the portion of electromagnetic wave which is polarized. It is defined by the ratio of the intensity of light in the direction of the vibration plane minus the intensity of the light perpendicular to it with the total intensity of light.

$$\rho = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

When the light is unpolarized, the degree of polarization is zero, otherwise when the light is polarized, it will give the value of 1.

2.4 The Polarization of Skylight

The light from the sun is naturally unpolarized, when it is entering the earth's atmosphere it will be partially linearly polarized by scattering interaction with the atmospheric material (gases, aerosol material, water droplets, icy crystals). The skylight has the properties of polarization patterns which is depending on the position of the solar, the spreading of the atmosphere components and the underlying surface properties (Horvath, 2004).

The phenomenon of the blueness of sky occurs by the scattering of the direct light from sun with the atmosphere's molecules. This phenomenon is known as the Rayleigh scattering, where the blue end of the light spectrum occurs when the light from the sun is scattered at a large angle with respect to the direction of the initial light from the sun. The scattered intensity of this phenomenon could be determined by using Rayleigh's Law.

$$I = I_O \frac{8\pi^4 N\alpha^2}{\lambda^4 R^2}(1 + cos^2\theta)$$

$N = Number\ of\ scatterers$

$\alpha = Polarizability$

$R = Distance\ from\ scatterer$

Based on the Rayleigh's Law, the blue sky will be given if the strong wavelength dependence of Rayleigh scattering enhances the short wavelengths.

The polarization of skylight could be used to describe and determine the indicators of atmospheric turbidity such as dust, haze, pollution and others as well as to determine the surface properties. The measurement of skylight polarization could be determined with point-source polarimeters to determine the degree and angle of linearly polarized light at different wavelengths.

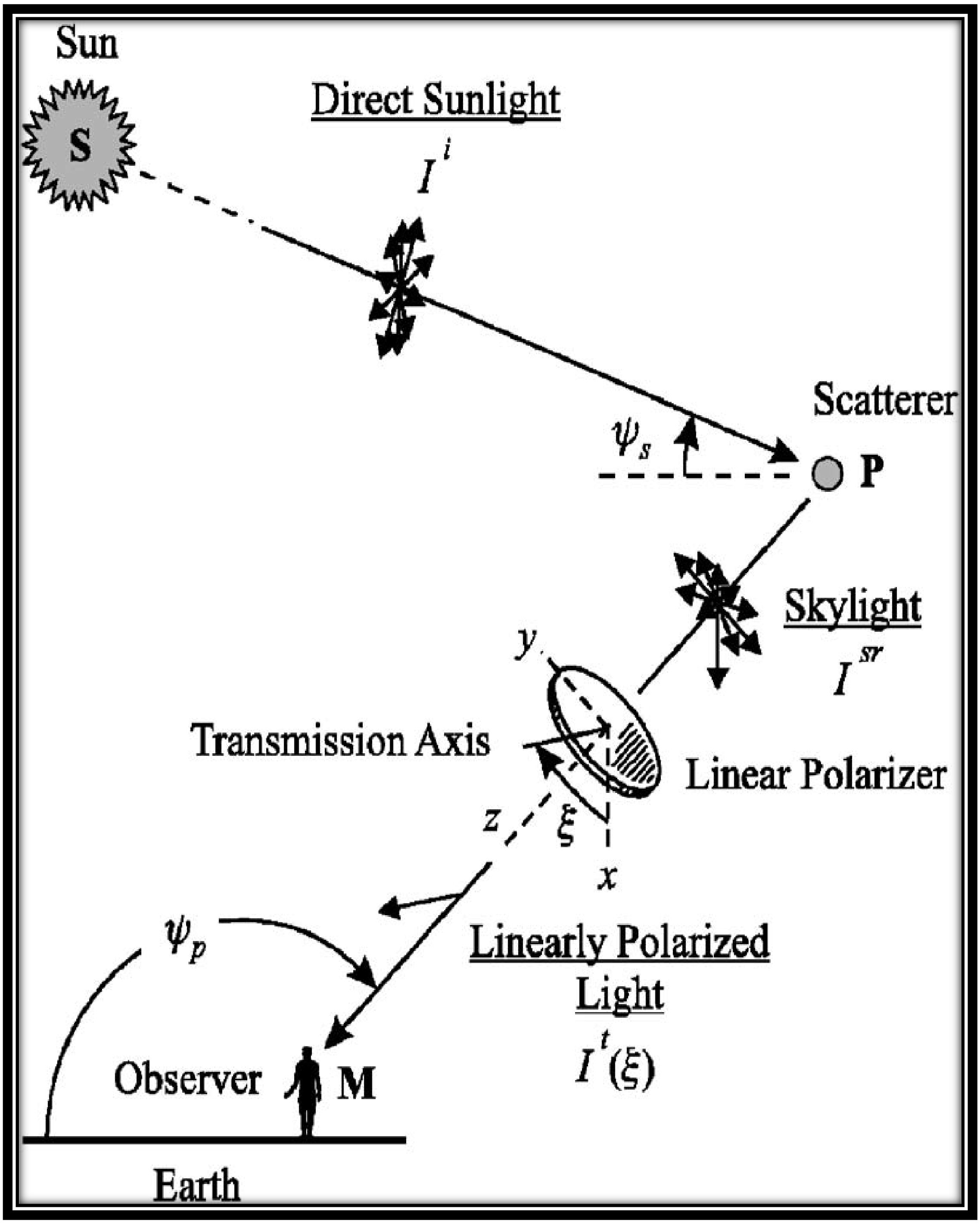


Figure 9 : Schematic drawing for observing the polarization of skylight (Smith, 2007).

2.5 The Polarization in Imaging of Human Skin

The polarization of light could be used to detect the pathology in skin or skin diseases or lesions by obtaining the visual record of medical imaging skin diseases or lesions. The fundamental concept of this subproject is by obtaining the images of the skin diseases or lesions and comparing the obtained images appearances to the closest appearances images in the references so that the preliminary analysis of the skin diseases or lesions could be done.

The preliminary analysis of the skin diseases or lesions might concern onto the color and texture of the superficial layers of the epidermis of human skin. Most of the skin diseases occur in the superficial layers of the epidermis. However, the ability of human eyes has difficulty to see directly the superficial layers of the epidermis, due to the backscattered light by which come from the deeper tissue layers (Jacques, Roman, & Lee, 2000).

In addition, the signs of aging of human skin are highly variable. As human age, changes in skin characteristics are more sensitive, thinner, more light penetrable and dry as well more wrinkled and flexibility loss (Öztürk, Engin, Engin, & Bayrak, 2010). Then polarization in imaging of human skin could detect the sign of aging at human skin. Therefore with the aid of current advances in computer and image technology, the visual record of medical imaging of the skin color and texture has become essential.

2.6 Polarization and its Effect on Imaging

As mentioned earlier, the polarized light occurs when the unpolarized light hits on an object and it will be reflected as polarized light. However, due to the light scatters from any directions, so that when it is polarized, its direction also will be scattered to any directions. The reflected polarized light sometimes can cause bad visualization on imaging. Therefore, a polarizer sometimes is used to allow only light with a specific angle of vibration to pass through the camera so that the image will have good visualization.

In Computer Vision field, an image can be analyzed based on its characteristics, such as edge, texture, pattern and other image features by using image processing technique. This project focuses on the effect of polarization on imaging to analyze the texture characteristic of imaging.

Texture is actually a variation of data at small scales which is smaller than the scales of interest (Petrou & Sevilla, 2006). For instance, in a picture of 50 cent Ringgit Malaysia If we are interested in identifying the coin, the pattern of hibiscus flower on the coin is considered as texture. Meanwhile, if we are interested in identifying the hibiscus flower or the number of 50 on the coin, those are considered as a non-textured object, due to those can hardly see any details inside them.

Texture can become a disturbance in computer vision system to identify an object from its shape. However, it can be an essential indication in object identifying because it gives us the information about the material which made the object. In computer vision, an image processing technique can solve at least three problems which dealing with texture:

- Texture classification, it is identifying a surface which represented by analyzing the texture on an image.
- Texture segmentation, it is dividing the image into different regions of textures.
- Texture defect detection, it is analyzing a texture either it is the same as expectation or contains false.

2.7 Stationary grey texture and Non-stationary grey texture images.

In computer vision, to extract the information of texture on imaging, an image can be converted into grey scale image, then by using others image processing technique this image can be proceed to be analyzed its texture features. There are two major types of texture image, those are stationary grey texture and non-stationary grey texture images.

2.7.1 Stationary grey texture images

A stationary grey texture image is an image which only has a single type of texture, for instance, the same texture covers up the whole image so that the image properties are located everywhere inside the image. The stationary grey texture image is used to identify the texture classification. It seeks a few numbers which is called as texture features that obtain the characteristics of certain texture, so that they can be used to identify the texture.

Some methodologies that can be applied to characterize stationary grey image are grey scale mathematical morphology, markov random field (MRF), Gibbs distribution, autocorrelation function, fourier transform and co-occurrence matrices. However, a grey image may be converted into a set binary image by using a thresholding method or bit-slicing to characterize the texture features (Petrou & Sevilla, 2006).

2.7.2 Non-Stationary grey texture images

If a stationary grey texture image only has a single type of texture, while a non-stationary grey texture image has more than one type of texture inside the whole image. This image is used to analyze the texture segmentation which is occupied by any single type of texture. The famous methodology that used to analyze the texture segmentation is Gabor filter.

CHAPTER III

METHODOLOGY

3.1 Procedure doing the project

3.1.1 Obtaining all the required materials and equipment

On this project, the image's samples are taken by using a DSLR camera with special macro lens which is able to capture a specific detail of texture in an object. This macro lens is also useful to get a good visualization of image for analyzing the human skin texture and pattern. Afterwards, the amount of light that passing to the camera must be considered. The more light that passing to the camera the brighter image will be captured and it will be hard to analyze. It can be set by adjusting the shutter speed on the camera mode. In addition, when using the additional polarized light, the angle of incoming light also must be considered.

3.1.2 Obtaining the image samples

Following the objectives of this project to analyze the texture of an image due to polarization of light, the objects for this project is focusing on some materials that having a texture pattern, i.e. tie, shirt, shock, coin, as well as the human skin. For the human skin, the target respondents are from the three major races, which are Caucasoid, Mongoloid and Negroid. Then, from each respondent will be taken their image's skin to be analyzed based on the texture of epidermis tissue layer.

The image samples of skin are focus on three part of human skin, which are skin of hand, cheek and skin around the hips back. All these part are easy to be observed to detect the texture of skin, sign of aging and color skin. An additional polarized light is required to light the specific skin area that will be captured so that the image sample will be easy to be analyzed.

3.1.3 Optimizing the degree of polarization by rotating the polarizer filter

The images are taken by two methods, which are using a polarizer filter lens and without a polarizer filter lens. By using a polarizer filter, it will allow only light with a specific angle of vibration to pass through the camera so that the image will have good visualization. Adjusting the degree of polarization must take into consideration during taking an image sample when using a polarizer filter lens. It can be adjusted by rotating the lens of polarizer filter into certain angle. The degree rotation of polarizer filter lens is rotated as counter clockwise, where the starting point is the 0/360 degree up to 315 degree.

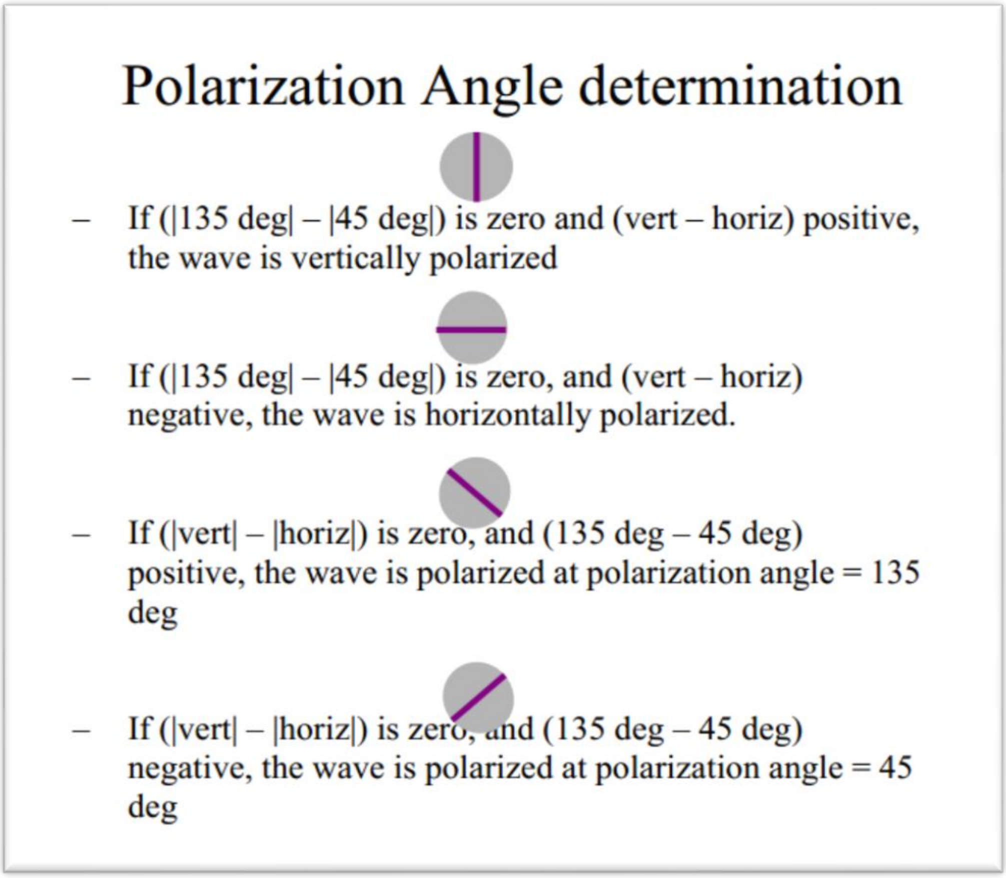


Figure 10 : Polarization Angle determination

During taking an image sample, the other things that must be considered are the position of camera and the focal length of lens. The position of camera must be remaining stable and no deviation angle that can change the image result as well as the focal length of lens, it must remain the same.

3.1.4 Subjective Analysis for the Image Sample

The subjective analysis is being done by collecting all image samples into one file to be selected subjectively by some respondents. For this project, the number of respondents is limited up to 20 respondents. The respondent must give a mark for at least 10 images which taken by using polarizer filter with different degree of polarization as well as without polarizer filter. The images are marked based on the respondent visualization, i.e. the brightness, light reflection, image color and others. The most chosen image by respondent will be considered as the basis image for comparing other images on objective analysis. The subjective analysis is shown in the Appendix A.

3.1.5 Analyze the image samples by using image processing technique on MATLAB.

The analysis will be based on focusing on the texture feature of an object. The Gabor filter is used to extract the texture feature from the image samples. Meanwhile, the Gaussian filter is used to detect the edge of the object on the image samples. In project, we applied the Gabor filter and multiply it with the Gaussian window to get the texture image from its reconstructed image. The reconstructed image is obtained by summing up the inverse Fourier transform of the frequency inside the image samples with the Gaussian filter. The higher frequency is the better texture's image to be visible.

Another method on this project is by using Modulation Models. This method is based on 2-D Amplitude Modulation-Frequency Modulation (AM-FM). It specifically uses the Dominant Component Analysis method, where it identifies the texture locally in terms of AM-FM signal and then it can be used as a texture descriptor. By using this method, we can analyze the image characteristic, such as the texture synthesis, edge synthesis as well as the probabilistic of texture's image.

3.2 Research Methodology

Research is a method taken in order to gain information regarding the major scope of the project. The sources of the research cover the handbook of polarization of light, e-journal, e-thesis and several trusted link.

The steps of research:

1. Gain information of the basic knowledge of polarization, the classification of polarization, the method of polarization, and degree of polarization.

2. Focusing on the specific topic of the polarization of skylight as well the imaging of human skins and methods to obtain the data.

3. Verify the obtained information to supervisor to ensure the method that will be used is valid for the project.

3.3 Flow Chart of Methodology for Polarization of Skylight

1
- Obtaining the related articles, journals, papers, books and other sources information.
- Doing the literature review based on the collected articles

2
- Obtaining all the required materials and equipments
- Camera DSLR, polarizer lens, automatic polarizer lens.

3
- Learning the image processing technique for polarization analysing by using MATLAB program

4
- Taking several samples of images, which is concerned on the skylight imaging.
- Please note that the methods of taking the images' samples must be concerned : no deviation, position must be constant and the angle must be the same.

5
- Optimizing the degree of polarization by rotating the polarizer lens as counter clockwise at certain degree from 0 degree to 360 degree.

6
- Doing the subjective analysis to get the required image for further experiment
- Subjective analysis is done by asking to 20 respondents to comment to the image samples.

7
- Analyzing the image sample by using the image processing technique with MATLAB program.
- Analyzing the least of reflection on imaging.

8
- Record all data obtained into the graph.
- Finish the experiment and move to the paper work.

3.4 Key Milestones of Project Activities

No	Activities	Date
Final Year Project I		
1	Topic selected	2 February 2012 (Week 2)
2	Literature review studies	Week 3 – Week 12
3	Proposal Extended Submission	5 March 2012 (Week 7)
4	Oral defense presentation	21 March 2012 (Week 9)
5	Getting the image sample and Subjective Analysis	14 April 2012 (Week 12)
6	Draft of interim report submission	20 April 2012 (Week 13)
7	Final interim report submission	27 April 2012 (Week 14)
Final Year Project II		
8	Progress Report Submission	9 July 2012 (Week 8)
9	Pre-EDX evaluation	Week 11
10	Draft Report Submission	8 August 2012 (Week 13)
11	Final Report (Soft Cover) Submission	15 August 2012 (Week 14)
12	Technical Paper Submission	15 August 2012 (Week 14)
13	Final Year Project II Viva (Final Evaluation)	23 – 28 August 2012 (Week 15)
14	Final Report (Hard Cover) Submission	10 September 2012 (Week 17)

Table 1: Key milestone of project activities

3.5 Activities/Gant Chart

No	Detail/Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Selection of Project Topic: Analyzing the effect of polarization in imaging							Mid-Semester Break								
2	Preliminary Research Work: Research on literatures related to the topic															
3	Submission of Proposal Extended															
4	Project Work: Study on the research scope and method															
5	Submission of Progress Report															
6	Presentation of Proposal Defense															
7	Project work continues: Further investigation by getting the images samples of the skylight and reflection.															
8	Subjective Analysis for Polarization of Skylight															
9	Submission of Interim Report Final Draft															
10	Project work continue: Getting the images sample for the polarization of human skin.	**DURING THE SEMESTER BREAK**														
11	Laboratory Activities 1 (During the semester break): Objective Analysis by using MATLAB Program	**DURING THE SEMESTER BREAK**														

Table 2: Gant Chart Table of FYP I

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Obtaining the required image samples.								Mid-Semester Break							
2	Obtaining image sample of human skin, for three major races.															
3	Submission of Progress Report															
4	Project Work: Creating the MATLAB programming code for objective analysis.															
5	Project Work: Analyzing the texture pattern of image samples and the effect of polarization on it.															
6	Pre-SEDEX Evaluation															
7	Project work continues: Further investigation of the previous results analysis.															
8	Draft Report Submission															
9	Final Report (Soft Cover) Submission															
10	Technical Paper Submission															
11	Final Year Project II Viva (Final Evaluation)	**WEEK 15**														
12	Final Report (Hard Cover) Submission	**WEEK 16**														

Table 3: Gant Chart Table of FYP II

CHAPTER IV

RESULT AND DISCUSSION

4.1 Data Gathering and Analysis

Following to the objectives of this project which focus on the analyzing the texture pattern of images due to the polarization of light, the image samples have been obtained and collected according to the methodology. The obtained images are obtained by using camera DSLR with concerning to the degree of polarization of the polarizer filter. Afterwards, the obtained images are spreading to the respondents to be done the subjective analysis. The subjective analysis table and result are shown in Appendix A.

Then, to analyze the texture pattern on the obtained image samples, we are using image processing technique on MATLAB programming software. The image analysis is using Gabor function to detect the texture pattern and the edge. By using different frequencies and orientations on this filter, it can be used for extracting the texture feature from the images.

Gabor filter can indicate a signal in time domain as well as frequency domain. To analyze an image, we use a Gabor function which generalizes in 2D, which is formulated as:

$$G\left(x, y; x_0, \omega_{x_0}, \sigma_x, y_0, \omega_{y_0}, \sigma_y\right) \equiv e^{-\frac{(x-x_0)^2}{2\sigma_x{}^2}-\frac{(y-y_0)^2}{2\sigma_y{}^2}} e^{j\omega_{x_0}x + j\omega_{y_0}y}$$

Then, the Fourier Transform of this filter is:

$$\hat{G}\left(\omega_x, \omega_y; x_0, \omega_{x_0}, \sigma_x, y_0, \omega_{y_0}, \sigma_y\right) \equiv 2\pi\sigma_x\sigma_y e^{-\frac{\sigma_x^2(x-x_0)^2}{2}-\frac{\sigma_y^2(y-y_0)^2}{2}} e^{-j(\omega_y-\omega_{y_0})y_0-j(\omega_0-\omega_{x_0})x_0}$$

According to (Petrou & Sevilla, 2006), the analyzing an image can be proceed by taking Discrete Fourier Transform (DFT) of the image itself and multiply the image by using Gaussian filter and then do the inverse Fourier transform of the result. The Gaussian filter is used to isolate a local patch of the image. Then, by tessellating the frequency into rectangular bands and place Gaussian filter inside so that we can ensure the possible frequencies within the image.

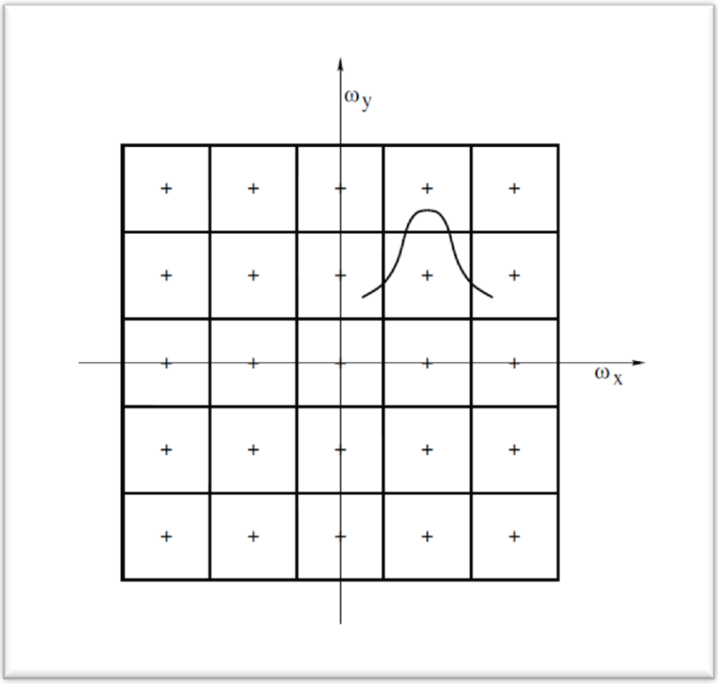


Figure 11: The schematic tessellation of the 2D frequency domain.

According to the figure above, the crosses mark are the centers of the frequency bands where the 2D Gaussian filter is placed. By multiplying it with the Fourier transform of the image, we can remove the frequencies outside the chosen frequency band and we can keep the frequencies inside the chosen bands. Afterwards, this result will be transformed back by using Fourier transform and it will produce an image which consists only frequencies in the chosen band. The result of this image will show us, the dark and structureless part is the part that not consist the frequencies.

4.2 Experimentation/Analysis on MATLAB

4.2.1 Analysis using Gabor function to reconstruct image

By using image processing technique in MATLAB, we analyze the effect of polarization on image, to identify the image's texture. The size of image must be resized up to 50% lower than the original size. An image must be converted first into gray scale image. Then with the aid of MATLAB program, the image will be analyzed by using Gabor function to identify or recognize the texture of an image.

Figure 12: The turkmen traditional shock as image sample for texture analysis

Giving the example of the image above, now we will analyze its texture pattern by using the Gabor filter. This image has 480x720 in size. Therefore, the frequency which are present in this image are in the ranges [-240, 239] and [-360, 359]. Then, we can determine the basic frequencies along the two axes are:

$$\frac{2\pi}{480} \text{ and } \frac{2\pi}{720}$$

Based on the basic frequencies above, we choose one of them to be our basic frequency, ω_0, where it is determined by the formula:

$$\omega_0 = 10\ x\ \frac{2\pi}{480}$$

$$\omega_0 = 0.131$$

Then, we determine the highest frequencies within the image along the two axes, which is formulated as following:

$$\frac{\pi 478}{480} \text{ and } \frac{\pi 718}{720}$$

So, the highest frequency is $\frac{\pi 718}{720}$, and now we determine the $\omega_{max} = 3.13286$. Afterwards, we determine the number of octave that can fit among frequencies ω_0 and ω_{max}, by using the formula as following:

$$\hat{K} \equiv \log_2 \frac{\omega_{max}}{\omega_0} = \log_2 \frac{3.13286}{0.131}$$

$$\hat{K} \equiv 4.58$$

This number used to determine the amount of radial bands that required covering the whole frequency space. For the further analysis, we determine other parameters such as the center of band, the bandwidth of band, the standard deviation and also the bandwidth in the tangential direction. All of them are formulated as following:

the center of band: $\rho_i = \frac{\omega_i + \omega_{i-1}}{2} = \frac{1}{2}\left(2^i\, \omega_0 + 2^{i-1}\omega_0\right) = 2^{i-2}\omega_0$

the bandwidth of band: $\Delta\omega_i = \omega_i - \omega_{i-1}$

the standard deviation: $\sum_{xi} = \frac{2^{i-2}\omega_0}{\sqrt{2ln2}}$

the standard deviation in tangential direction: $\sum_{yi} = \frac{\rho_i}{\sqrt{2ln2}} \tan\frac{\Delta\varphi}{2}$

By putting the values inside the above formula, then we can determine each parameters:

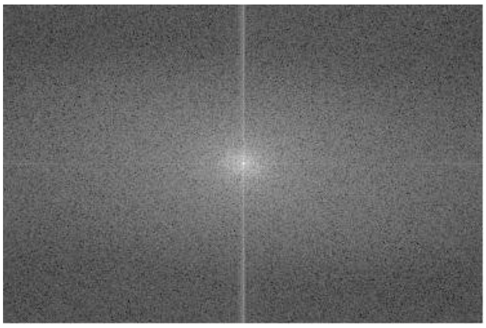
Radial band	ρ_i	$\Delta\omega_i$	$\sum_{\rho_i}$	$\sum_{\Phi_i}$
1	0.1965	0.131	0.05563	0.07088
2	0.393	0.262	0.11126	0.13853
3	0.786	0.524	0.22252	0.27710
4	1.572	1.048	0.44504	0.55266
5	3.144	2.096	0.89009	1.10689

Table 4: Values of parameters $\rho_i, \omega_i, \sum_{\rho_i}, \sum_{\Phi_i}$.

Then, we choose, L, the orientations for the directional filters along with the center of each Gaussian filter is placed. This parameter will be used together with the all parameter on the Table 3 above to create the Gaussian masks.

4.2.2 Result on MATLAB Analysis

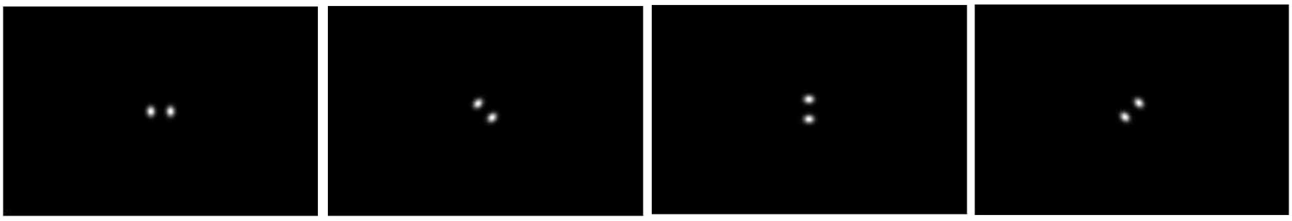
(a) Grayscale original image



(b) Magnitude of its Fourier transform

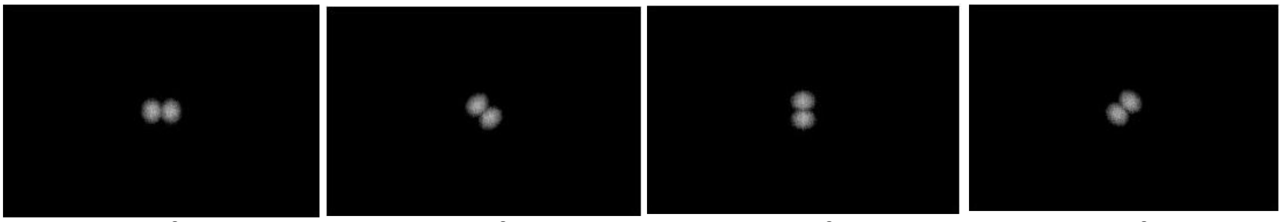
Figure 13: (a). Grayscale original image, (b). Magnitude of its Fourier transform

Figure 14: Filter mask on scale 1



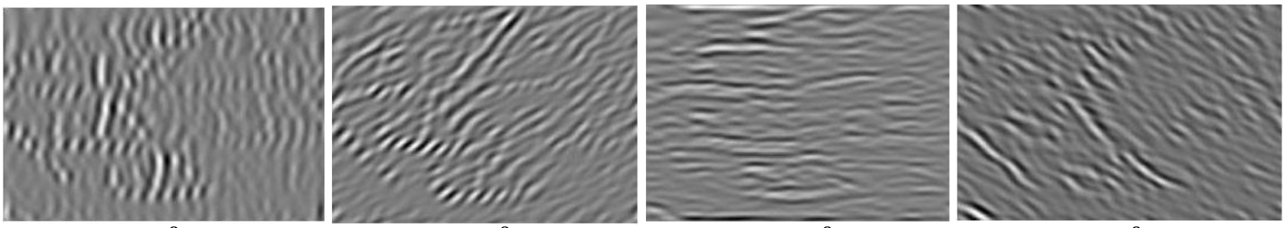
0^o 45^o 90^o 135^o

Figure 15: FT filtered on scale 1



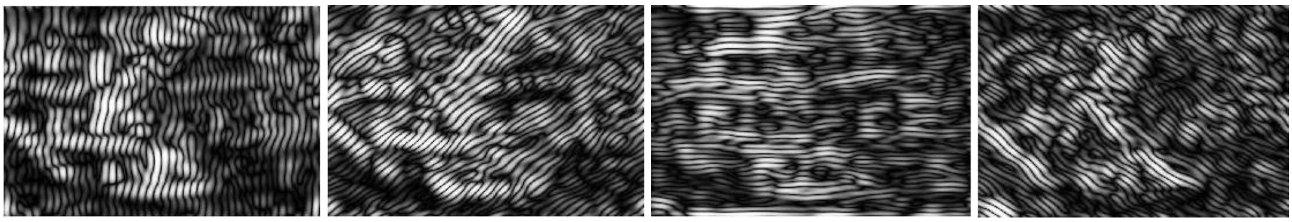
0^o 45^o 90^o 135^o

Figure 16: IFFT filtered on scale 1



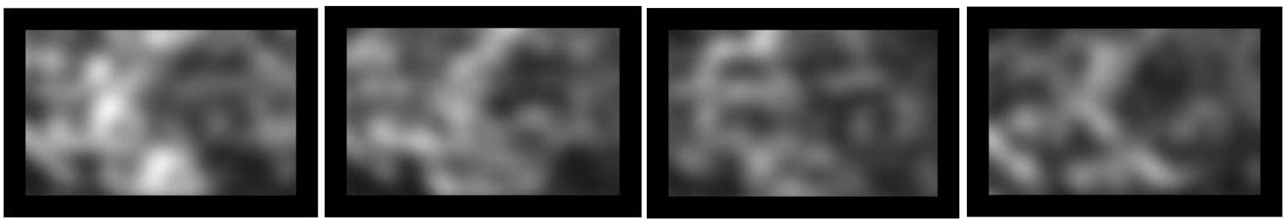
0^o 45^o 90^o 135^o

Figure 17: psi on scale 1



0^o 45^o 90^o 135^o

Figure 18: Local energy on scale 1



0^o 45^o 90^o 135^o

The figure 15 shows the results of multiplying the Fourier transform of the image with the Gaussian masks. All the image results has the same scaling between range 0-255 and it allows visual comparison among the different panels. The figure 16 shows the visualization of inverse Fourier transform of the filtered image. Meanwhile, the figure 17 shows the visualization of the $\varphi(g)$ transformations of the panels. It is representing the existence of positive and negative values within the image.

$$\varphi(g) = \left| \frac{1 - e^{-2\alpha g}}{1 + e^{-2\alpha g}} \right|$$

α = variable parameter which is greater than 0

g = the value of grey within the reconstructed image.

This transformation causes the effect of resolving the wave by creating both its lobes positive as well as to broaden them into stripes. The figure 18 shows the visualization of image of the local energy features which computed from the panels. The local energy is computed by using a Gaussian window to average the $\varphi(g)$ values within the local window around each pixel. The result will produce the reconstructed image. All these step above are repeated for 5 times, since our K value is 5. The result images are shown in the Appendix B and Appendix C for the reconstructed images.

4.2.3 Analysis using Gabor Function and Gaussian Filter by using Modulation Models

Another method that applied for this analysis is by using the Modulation Models with the aid of Gabor and Gaussian Filter. In this method, the image sample will be processed into Amplitude Modulation – Frequency Modulation (AM-FM) image models as well as Dominant Component Analysis (Havlicek, Harding, & Bovik, 2000).

In this method, we processed image by using some techniques of filtering and modeling as following:

- Gabor filtering for Model-based interpretation to identify or recognize the texture of an object.
- Additional models for edge detection and smooth signals by using Gaussian filter.
- Model comparison for texture, edge, and smooth classification.

In addition, by using this method we can also distinguish the difference between the texture synthesis and the edge synthesis.

4.2.4 Result Analysis on MATLAB

Figure 19: Original Image for Human Skin

(a). Without Polarized Filter

(b). With Polarized Filter

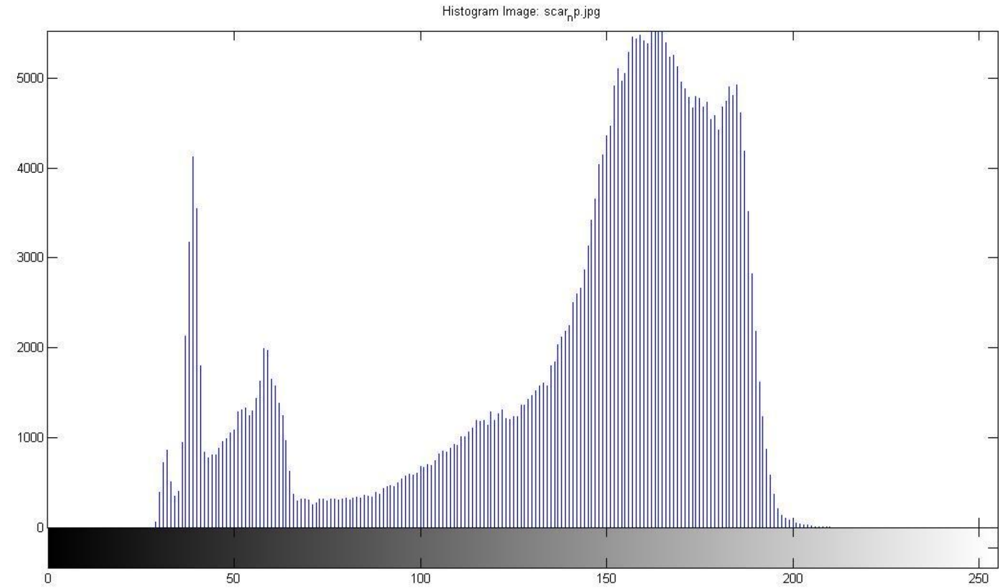
Figure 20: The grayscale image of the original image of human skin

(a). Without Polarized Filter

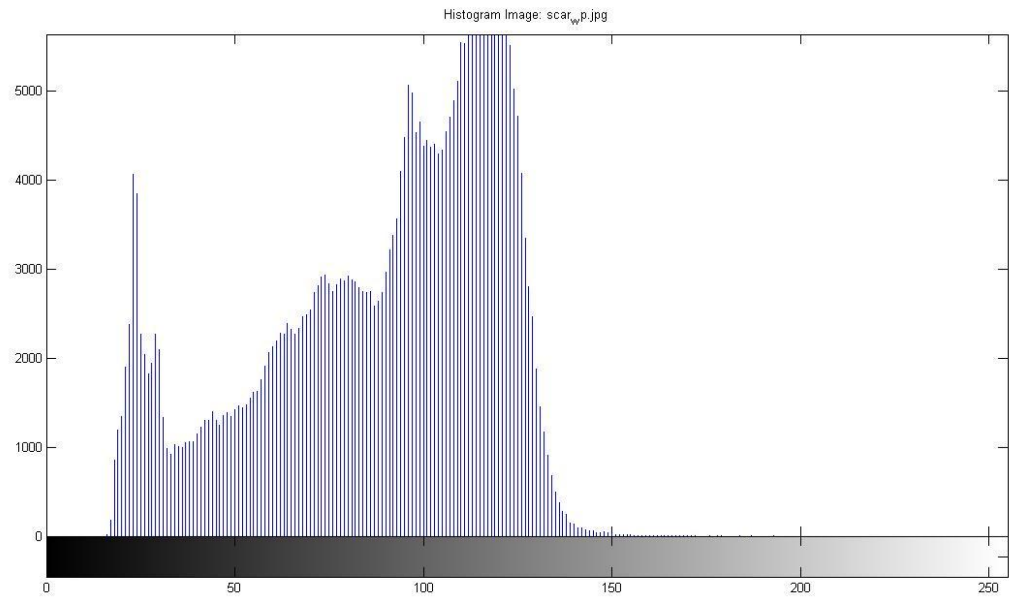
(b). With Polarized Filter

Figure 21: The Histogram of the Original Image of Human Skin

(a). Without Polarized Filter



(b). With Polarized Filter



Based on the Figure 19 (a and b), if we observe naturally the image by using our human eyes, the Figure 19b (with polarizer filter lens) will be a bad visualization for the observation due to the image characteristic such as, the image contrast and the image brightness is too dark. However, the Figure 19a (without polarizer filter lens) will be a good option for the observation, because the image contrast is not too dark and the image brightness is normal for the visualization.

In addition, we can distinguish the two images based on the intensity of the brightness of the images by observing on the histogram of the gray scale image. Looking to the Figure 21a (without the polarizer filter lens), the shape of the histogram is increasing close to the intensity of the white color. The BW (Black and White) color of the image between 150 and 200 has a lot of intensity, due to the intensity of light that capturing on the image and reflected on the skin. Meanwhile on the Figure 21b (with polarizer filter lens), the histogram shows the amount of BW (Black and White color) of the image is even less than 150 and it has a lot of intensity in range of 100 and 150.

However, if we only observe by looking at both images, we can hardly see the difference between the normal skin texture and the skin lesion texture. It is because texture is variation data at scales smaller than the interest scale. Therefore, further analysis on MATLAB algorithm by using Gabor function with Modulation Model is used to extract the texture and edge features from the image.

Figure 22: Result of Modulation Models on Human Skin Image: (Left) Without polarizer filter, (Right) with polarizer filter

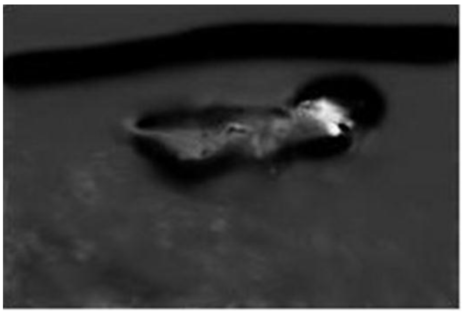
(a). Texture synthesis:

(b). Texture synthesis:

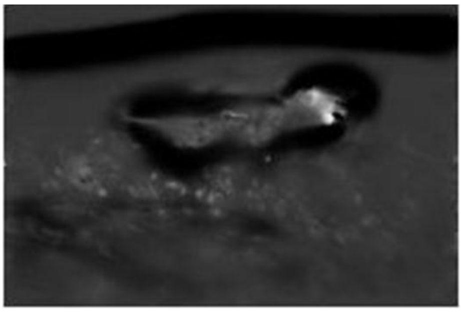
(c). Edge synthesis:

(d). Edge synthesis:

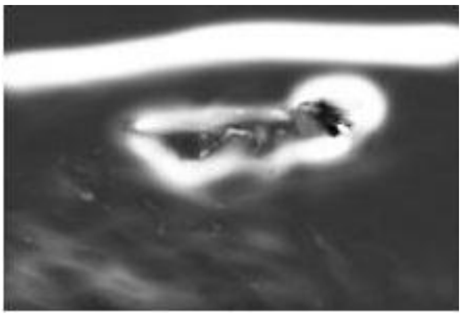
(e). P (Texture):



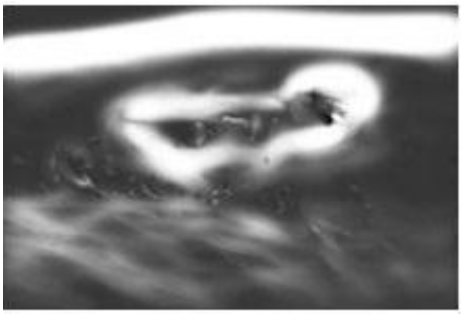
(f). P (Texture):



(g). P (edge):



(h). P (edge):



The figure 22a, 22c and 22e show the results of image processing on texture analysis of human skin image which is taken without polarizer filter. Meanwhile, the figure 22b, 22d and 22f show the results of image processing on analysis of human skin image with polarizer filter.

The figure 22a and 22b show the texture synthesis of image, which done by using Gabor function. As we can observe from those images, the one which is captured with polarizer filter (shown by Figure 22b), the texture of the skin as well as the texture of the scar are more visible. Meanwhile, the one which is captured without polarizer filter (Figure 22a) shows the texture of the skin and the scar is slightly difficult to be observed due the reflection of light on the skin image. In addition, to make sure on observation of the texture synthesis of the image samples,

The figure 22c and 22d show the edge synthesis of image, which done by using the Gaussian filter. The image which is captured with polarizer filter (shown by Figure 22c), the edge of the scar is more visible than the image which is captured without polarizer filter (Figure 22d). Therefore, it can say that the closer intensity to 1, the more of light is captured onto image and means that less edge will be visible on the image.

The Figure 22e and 22f show the probabilistic of the texture and edge of the image sample. It is yielded from the Gabor filter in terms of model fitting that can detect or recognize in common terms with texture analysis. This is used to distinguish between edge and textured area. Other examples of result are shown below and in Appendix E.

4.2.5 Result Analysis on MATLAB for Polarization Skylight

Figure 23: Original Image

(a). Without Polarizer Filter

(b). With Polarizer Filter

Figure 24: The gray scale image of the original image of car

(a). Without Polarized Filter

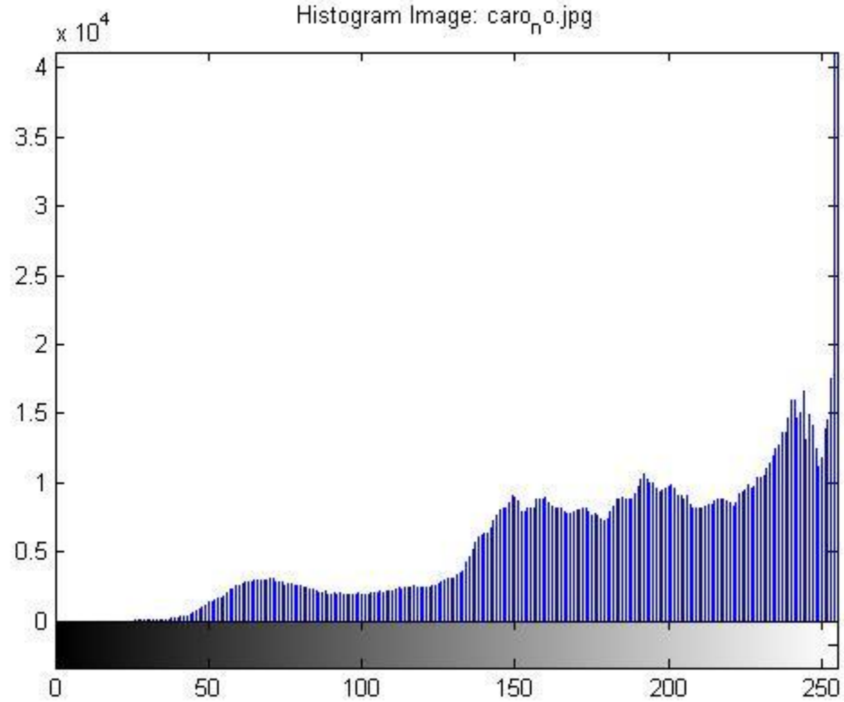
Image: $caro_no$.jpg

(b). With Polarized Filter

Image: caro(90).jpg

Figure 25: The histogram of the Original Image of Car

(a). Without Polarized Filter



(b). With Polarized Filter

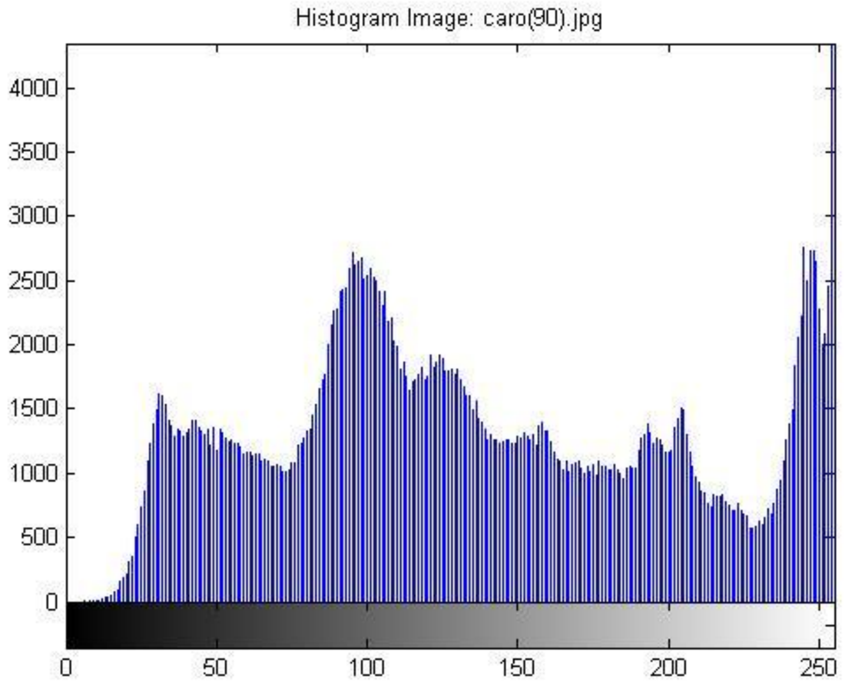


Figure 26: Result of Modulation Models on Polarization skylight. (Left) Without polarizer filter, (Right) with polarizer filter

(a). Texture synthesis:

(b). Texture synthesis:

(c). Edge synthesis:

(d). Edge synthesis:

(e). P (Texture):

(f). P (Texture):

(g). P (Edge)

(h). P (Edge)

4.3 Advantages using the Modulation Model

The Modulation model by using the Amplitude Modulation-Frequency Modulation (AM-FM) image model as well as the Dominant Component Analysis method can determine the discrimination between the texture and edge synthesis. By using this method also, the texture features which are derived from the Gabor filter can be dealt with by choosing the channels that maximally distinguish the different texture.

CHAPTER V

CONCLUSION & RECOMMENDATION

Extraction the texture features of an object can be done by using several methods, such as by using the Reconstruction Image, where the image is processed by using the Gabor filter as well as the appropriate Gaussian window. By using this method, all possible frequencies within the image must be considered, to obtain better results. Since, this method is based on the frequency that might be present in the image, so that it will determine the texture from the lower frequency up to the higher frequency. The higher frequency is the better texture is visible.

Another method by using the Modulation Model based on the Amplitude Modulation-Frequency Modulation image model and specifically the Dominant Component Analysis (DCA) method. This method is more reliable to extract the texture feature from an image, due to the use of the DCA as the representative of the texture locally in terms of the signal of AM-FM that having the information and parameter as a texture descriptor.

At last, the polarization actually can be used to identify or recognize a small object, like the texture or edges. However, it is also depends on the amount that reflect on the object. The more reflection of light from the object, it is harder to extract the texture features from the object. The use of polarization also can be useful in the medical field to diagnose better on analysis of skin disease or lesion. The proper polarization will help to identify or recognize the small texture or pattern of skin disease as well it can help to distinguish between the texture of skin itself and the texture of the skin lesion.

For further analysis on texture, the AM-FM/DCA method is quite reliable to be developed to analyze the image problems which are dealing with texture, edge or any object detection problem.

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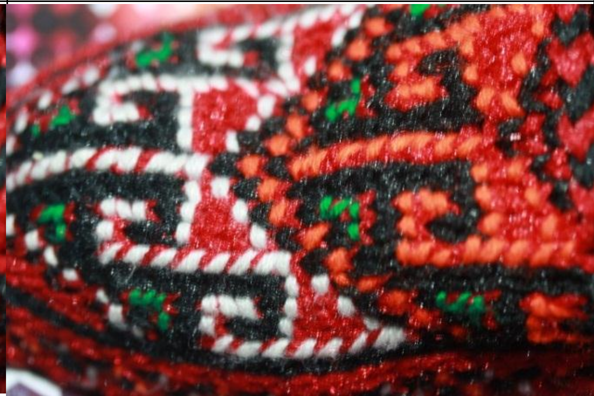
APPENDIX A:

SUBJECTIVE ANALYSIS RESULTS

Subjective Analysis

Method	A (No Polarizer)	B (Polarizer Filter at 0)	C (Polarizer Filter at 45)
Output Image			
Value	**1 (10), 2 (5), 3 (2), 4 (2), 5 (1)**	**1 (7), 2 (5), 3 (3), 4 (3), 5 (2)**	**1 (5), 2 (5), 3 (4), 4 (3), 5 (3)**
Method	D (Polarizer Filter at 90)	E (Polarizer Filter at 135)	F (Polarizer Filter at 180)
Output Image			
Value	**1 (4), 2 (5), 3 (5), 4 (4), 5 (2)**	**1 (4), 2 (4), 3 (5), 4 (4), 5 (3)**	**1 (6), 2 (4), 3 (3), 4 (3), 5 (1)**

Method	G (Polarizer Filter at 225)	H (Polarizer Filter at 270)	F (Polarizer Filter at 315)
Output Image			
Value	**1 (6), 2 (5), 3 (3), 4 (4), 5 (2)**	**1 (4), 2 (5), 3 (4), 4 (4), 5 (3)**	**1 (5), 2 (6), 3 (4), 4 (2), 5 (3)**

Method	A (No Polarizer)	B (Polarizer Filter at 0)	C (Polarizer Filter at 45)
Output Image			
Value	**1 (12), 2 (4), 3 (2), 4 (1), 5 (1)**	**1 (6), 2 (5), 3 (5), 4 (2), 5 (2)**	**1 (4), 2 (6), 3 (4), 4 (3), 5 (3)**
Method	D (Polarizer Filter at 90)	E (Polarizer Filter at 135)	F (Polarizer Filter at 180)
Output Image			
Value	**1 (9), 2 (5), 3 (2), 4 (2), 5 (2)**	**1 (5), 2 (5), 3 (6), 4 (1), 5 (3)**	**1 (7), 2 (5), 3 (3), 4 (3), 5 (2)**

Method	G (Polarizer Filter at 225)	H (Polarizer Filter at 270)	F (Polarizer Filter at 315)
Output Image			
Value	**1 (7), 2 (4), 3 (5), 4 (2), 5 (2)**	**1 (5), 2 (6), 3 (4), 4 (2), 5 (3)**	1 **(6), 2 (6), 3 (2), 4 (4), 5 (2)**

The given mark shown outside the bracket and have the values of parameters as following:

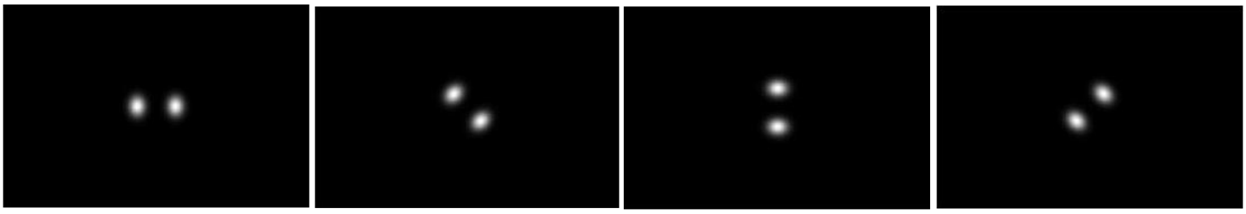
1 = Excellent
2 = Good
3 = Fair
4 = Bad
5 = Worst

The number of respondent is shown on the number within the bracket.

APPENDIX B:

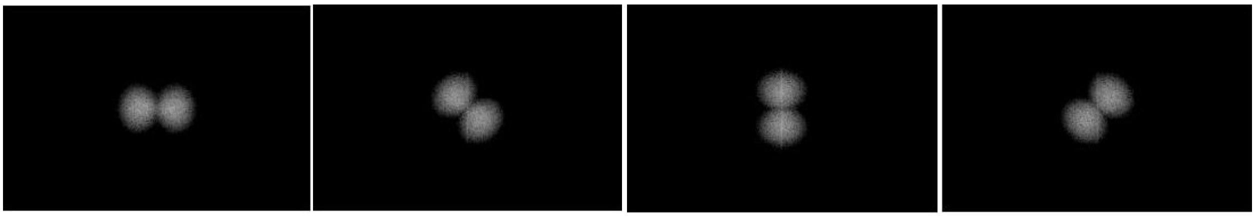
THE IMAGE RESULT BY USING RECONSTRUCTED IMAGE

A. Filtered mask on scale 2



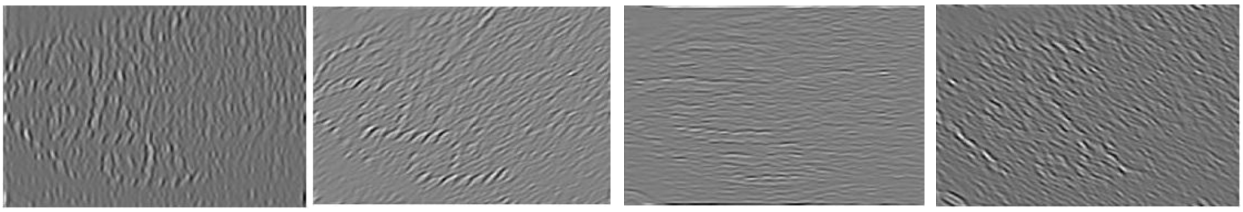
0^{o} 45^{o} 90^{o} 135^{o}

B. FT filtered image on scale 2



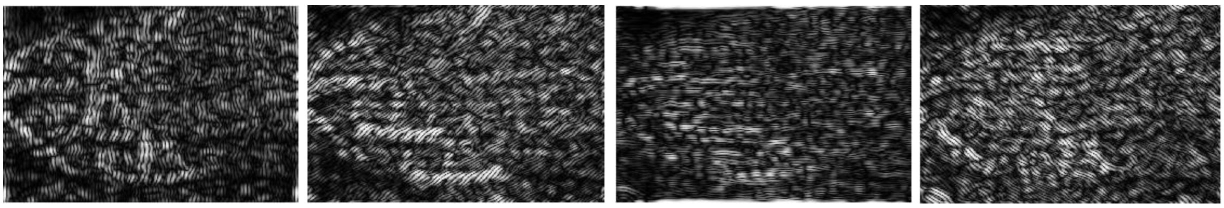
0^{o} 45^{o} 90^{o} 135^{o}

C. IFT filtered image on scale 2



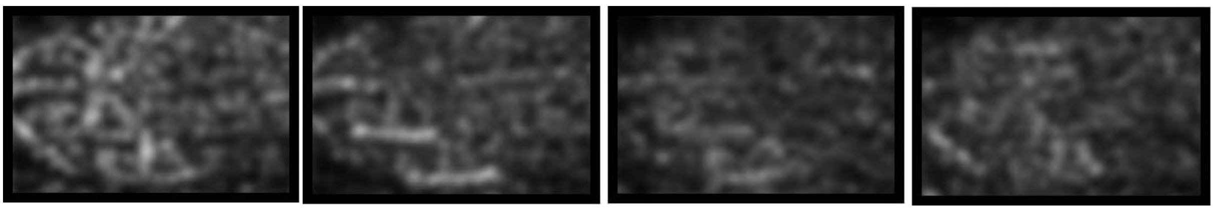
0^{o} 45^{o} 90^{o} 135^{o}

D. Psi on scale 2



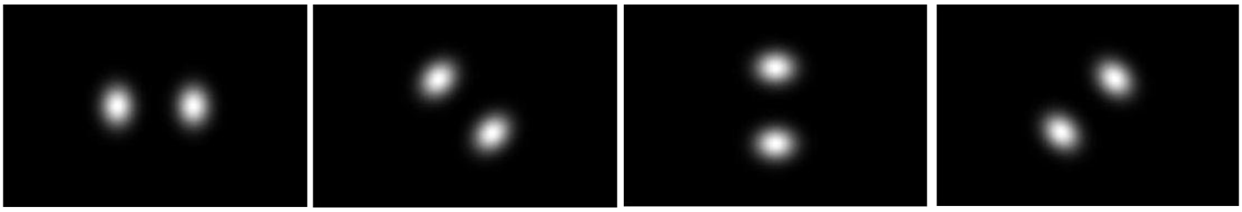
0^{o} 45^{o} 90^{o} 135^{o}

E. Local energy on scale 2



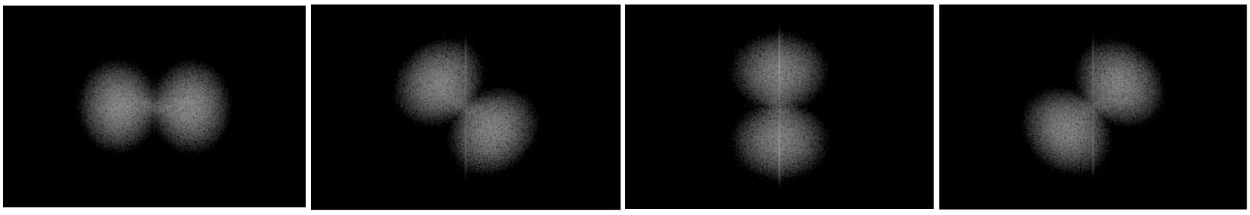
0^{o} 45^{o} 90^{o} 135^{o}

A. Filtered mask on scale 3



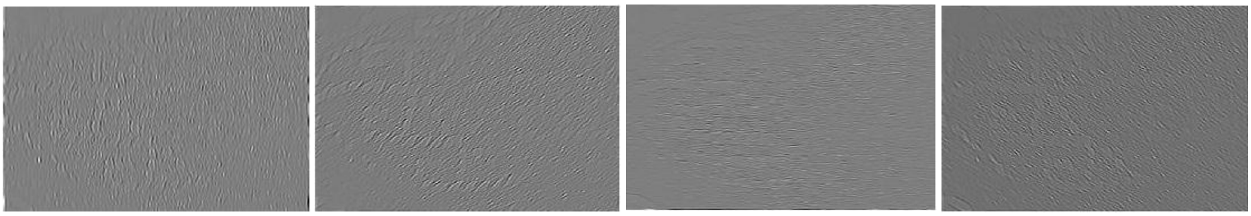
0^o 45^o 90^o 135^o

B. FT filtered image on scale 3



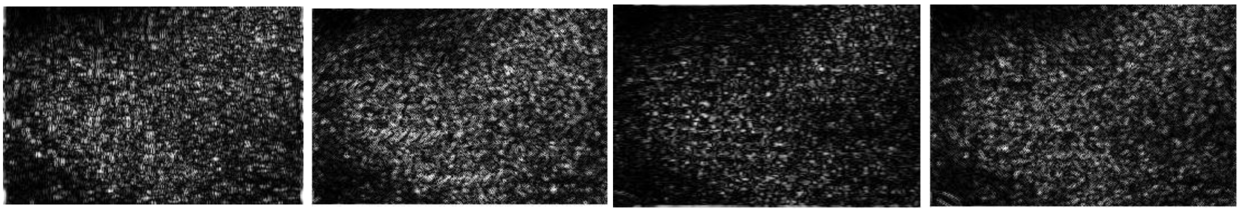
0^o 45^o 90^o 135^o

C. IFT filtered image on scale 3



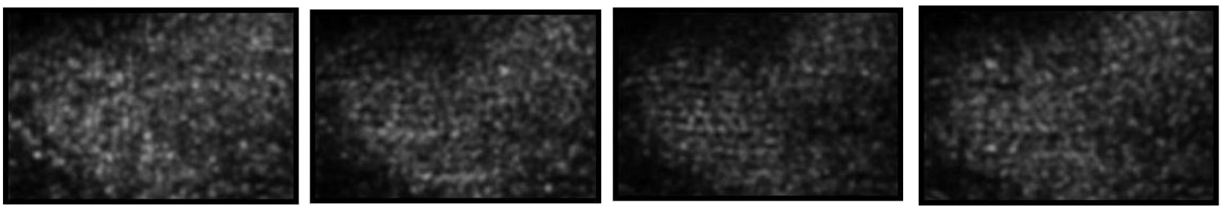
0^o 45^o 90^o 135^o

D. Psi on scale 3



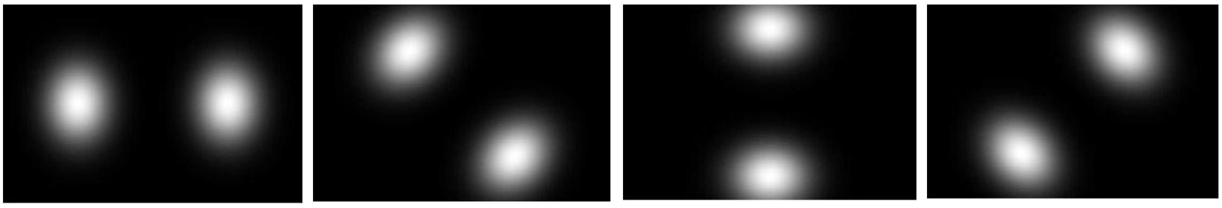
0^o 45^o 90^o 135^o

E. Local energy on scale 3



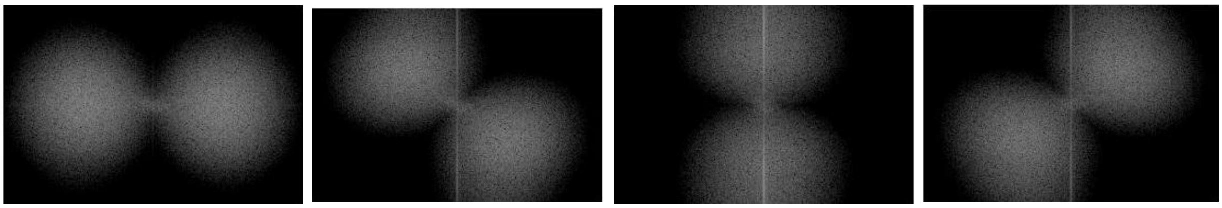
0^o 45^o 90^o 135^o

A. Filtered mask on scale 4



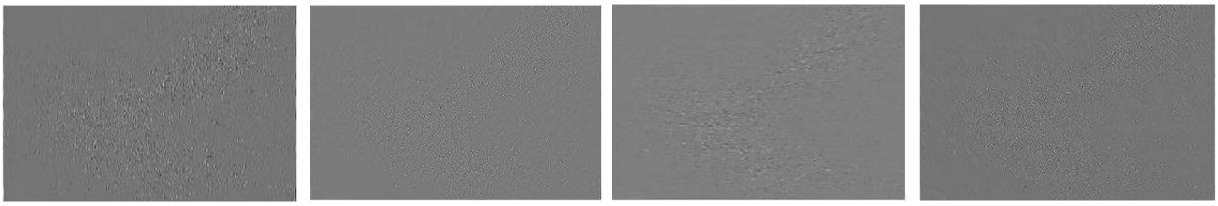
0^o 45^o 90^o 135^o

B. FT filtered image on scale 4



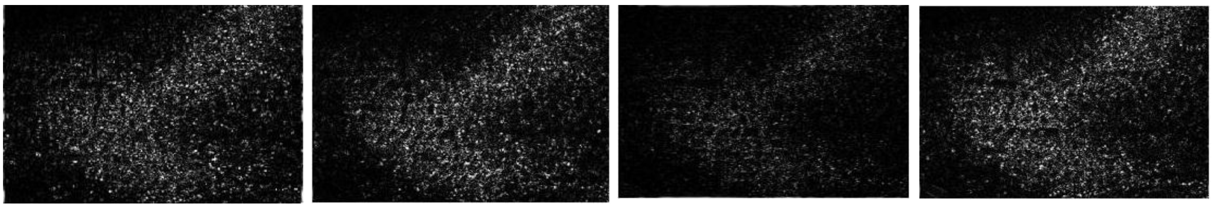
0^o 45^o 90^o 135^o

C. IFT filtered image on scale 4



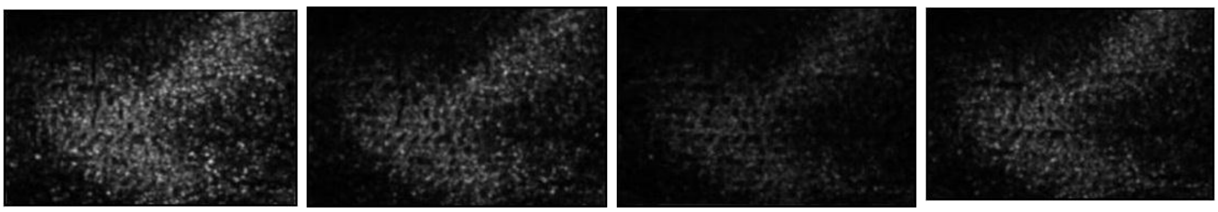
0^o 45^o 90^o 135^o

D. Psi on scale 4



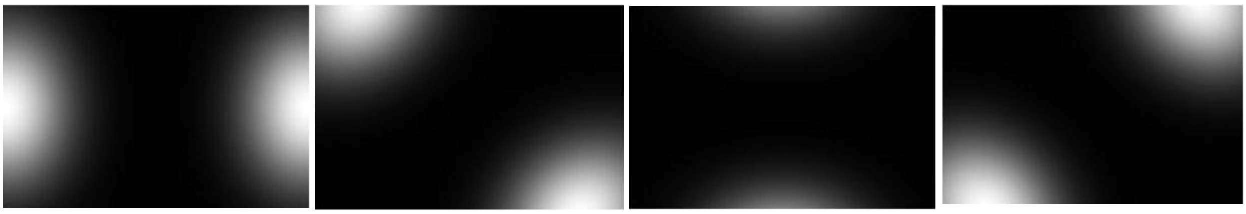
0^o 45^o 90^o 135^o

E. Local energy on scale 4



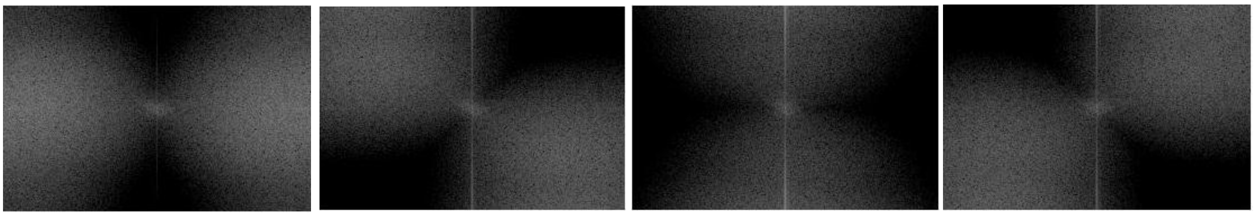
0^o 45^o 90^o 135^o

A. Filtered mask on scale 5



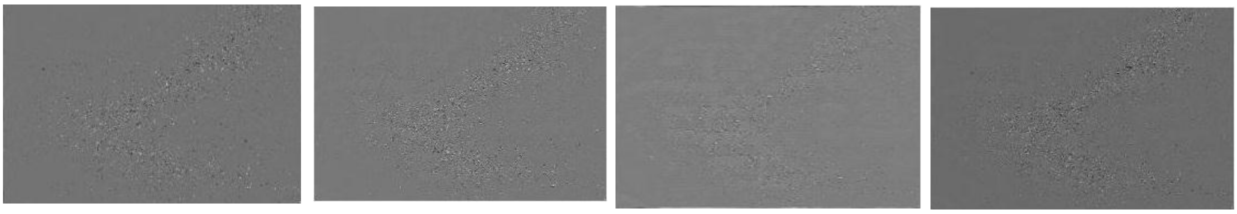
0° 45° 90° 135°

B. FT filtered image on scale 5



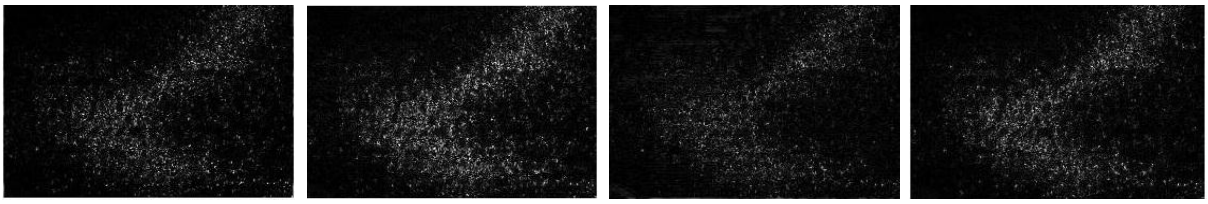
0° 45° 90° 135°

C. IFT filtered image on scale 5



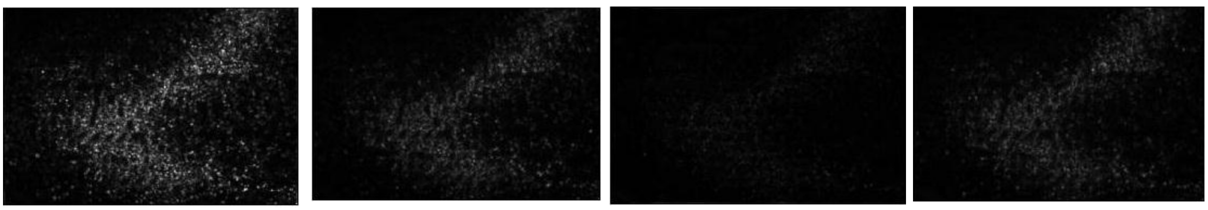
0° 45° 90° 135°

D. Psi on scale 5



0° 45° 90° 135°

E. Local energy on scale 5



0° 45° 90° 135°

APPENDIX C:

THE RECONSTRUCTED IMAGE

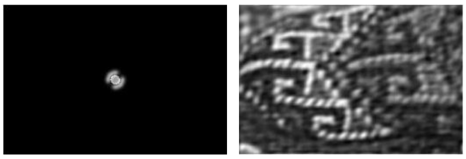
a. The central band containing the dc component of the image and reconstruction image.

b. The reconstructed image with n channels with the highest energy

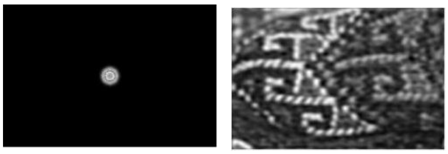
n=1

n=2

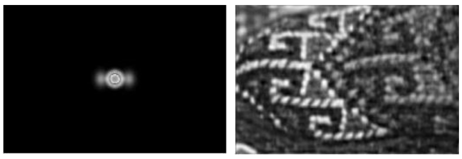
n=3



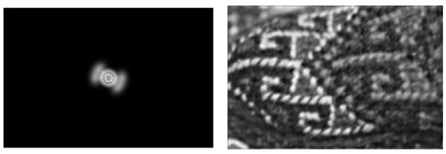
n=4



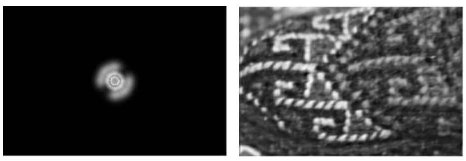
n=5



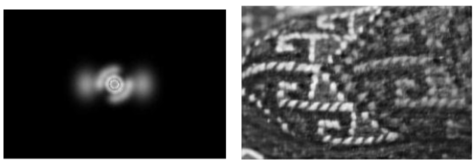
n=6



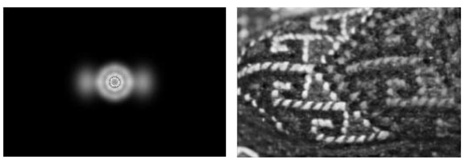
n=7



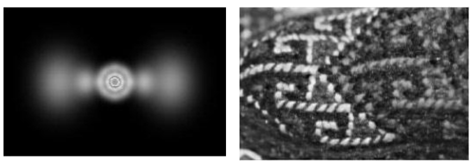
n=8



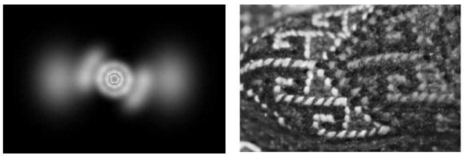
n=9



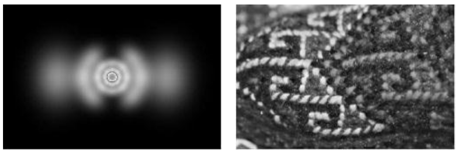
n=10



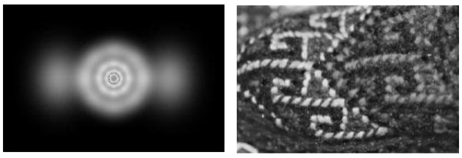
n=11



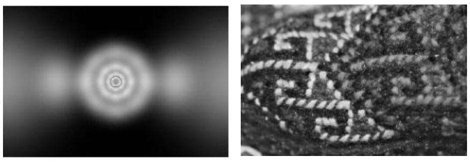
n=12



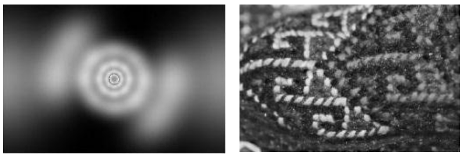
n=13



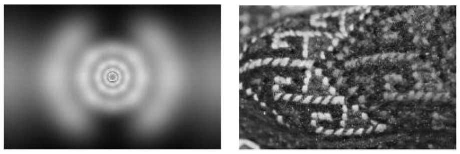
n=14



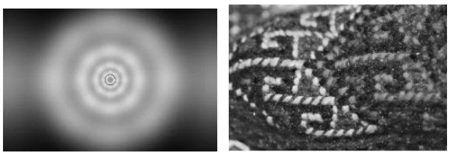
n=15



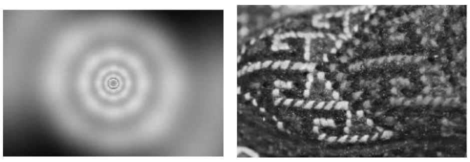
n=16



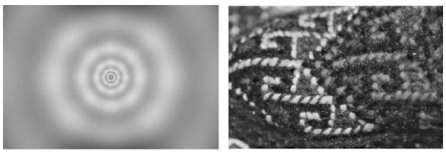
n=17



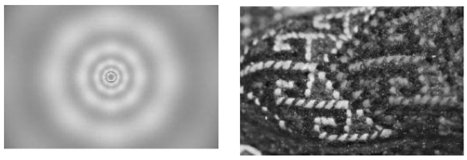
n=18



n=19



n=20



APPENDIX D :

IMAGE RESULT BY USING MODULATION MODEL

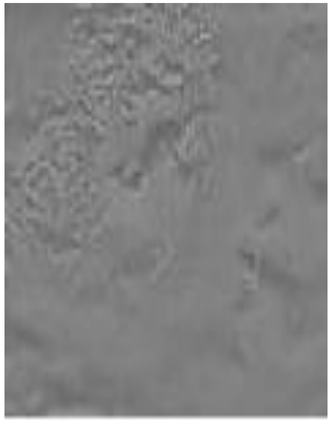
Without Polarized Filter

With Polarized Filter

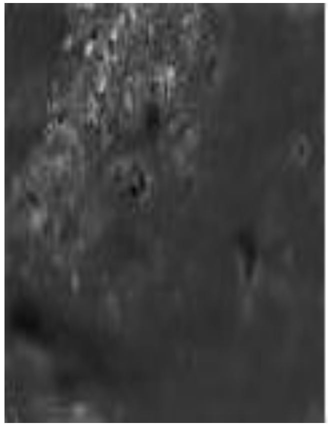
(Upper) Without polarizer filter, (Lower) with polarizer filter

Texture synthesis:

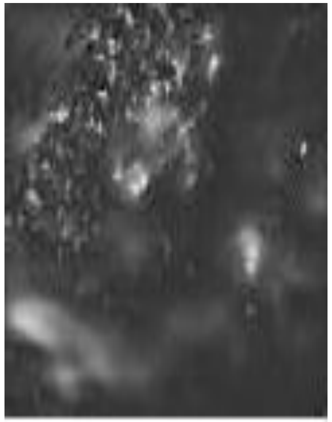
Edge synthesis:



P (Texture):

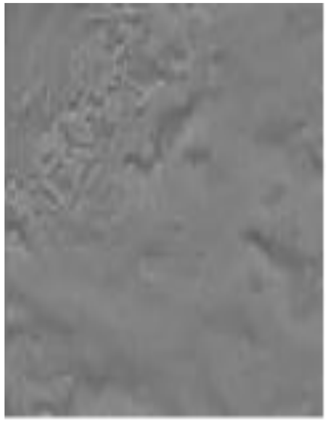


P (Edge):

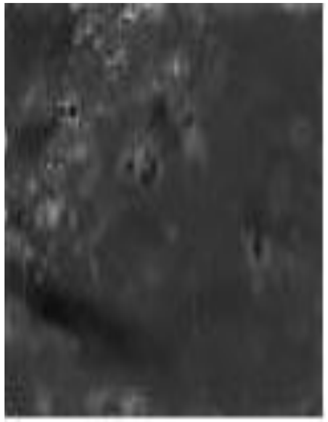


Texture synthesis:

Edge synthesis:



P (Texture):



P (Edge):