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A Study of the Image Quality for Human Eye

A Thesis

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By

Azhar Owied KAdhom

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Supervised by

Assistant Professor Dr. Salah A. Saleh

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُمْ بِمَا كُنْتُمْ تَعْمَلُونَ

صدق الله العظيم

(التوبة: ١٠٥)

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We certify that this thesis entitled "**A Study of the Image Quality for Human Eye**" was prepared by "**Mrs. Azhar Owied Kadhom**" under our supervision at College of Science, Al-Nahrain University as a partial fulfillment of the requirements for the degree of **Master of Science in Physics**.

Signature:

Name : **Dr. Salah A. Saleh**

Title : **Assistant Professor**

Date : **/ /2008**

In view of the available recommendations, I forward this thesis for debate by the examination committee.

Signature:

Name : **Dr. Ahmad K. Ahmad**

Title : **Assistant Professor**

Address: **Head of Department of Physics**

Date : **/ /2008**

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We certify that we have read the thesis entitled ***" A study of the Image Quality for Human Eye*** " and as an examination committee, examined the student **Mrs. Azhar Owied Kadhom** on its contents, and that in our opinion it is adequate for the partial fulfillment of the requirements of the degree of **Master of Science in Physics.**

Signature:
Name: **Dr. Layla S. M. Al-Ali**
Title: **Assistant Professor**
(Chairman)
Date: / /2008

Signature:
Name: **Dr. Mohammed S. Ahmed**
Title: **Assistant Professor**
(Member)
Date: / /2008

Signature:
Name: **Samir Khudhir Al-ani**
Title: **Assistant Professor**
(Member)
Date: / /2008

Signature:
Name: **Dr. Salah A. Saleh**
Title: **Assistant Professor**
(Supervisor)
Date: / /2008

Approved by the College Committee of Postgraduate studies

Signature:
Name: **Dr. LAITH ABDUL AZIZ Al- ANI**
Title: **Assistant Professor**
(Dean of the College of Science)
Date: / /2008

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ABSTRACT

The study of the effect of some factors on the human is difficult and complex because of the lack of instruments for measuring eye efficiency.

The human eye is an optical organ, its work is similar to the camera work, but the eye can not return the image which it makes, but the camera can return. Producing high quality image by human optical system like other lens system is affected by many parameters, some of them are internal such as aberrations and age, pigmentation. Also human eyes suffer from some defects that effect the human eye image quality, some of these defects are:

1. ***Hypermetropia (Long sightedness)***
2. ***Myopia (short sightedness)***
3. ***Some other defects***

The optical characteristics of human eye imaging system are studied quantitatively via experimental and computer modeling. Experimental work is carried out to study the effect of spatial frequencies, color and ages on image eye quality. Computer simulations models are carried out to study the limitations imposed by imaging in the human eye. These limitations include the diameter of pupil eye, the aberrations (astigmatism and spherical), age, and pigmentation of eye. These limitations are computed in terms of modulation transfer function (MTF).

The results showed that MTF curves are suitable for determining image quality and the limitions effect on imaging system. Also result showed a coincidence between laboratory work and theortical calculation of MTF for age, pigmentation, pupil size and aberrations.

Chapter One:

Introduction

Chapter Two:

The Human Eye

Chapter Three:

Theoretical Background

Chapter Four:

Results and Discussions

Chapter Five:

Conclusions and Future Work

CHAPTER ONE

INTRODUCTION

1-1 Introduction

From the earliest dawn of history, man must have wondered how the outside world became apparent to him through his eyes. He must have pondered what focuses cause an observing eye to see an object. Why did the world look light or dark or nature have such bright colors? Even though early man could not understand the concept of the physics of light or that perception occurred in the brain, he must have understood that the eye was the organ of vision and without the eyes we were blind. Thus, the earliest concerns of the ancient civilization of India, Babylon, China and Egypt were certainly to attempt to restore or improve eye sight when it was failing even without understanding much else. It was the Greek philosophers (Hippocrates, Aristotle, and Plato) who provided the first known theories concerning the eye, its function, anatomy and treatment.

Originally the Aristotelian idea was that rays of light emanated from the eyes to illuminate the world around. When it was dark, the air became murky so the rays could not penetrate but a candle could burn off the opacity in the air allowing sight to penetrate. Johannes Kepler (1571-1630) in his Dioptrice established of dioptrics fundamental to an understanding of how the image is formed in the eye. He understood that the cornea and lens collected and refracted the light rays and that the image was "painted" on the retina as an aggregation of many image points. Kepler was also able to explain presbyopia and myopia [1].

1-2 The optics of the human eyes and defects:

The main elements of the human eye is the iris and the pupil, which control the amount of light penetrating the eye ball; the cornea and crystalline lens, which together refract the light to create the retinal image .

The cornea is a transparent, highly curved refractive window through which light enters the eye before being partially blocked by the colored and opaque surface of the iris.

The pupil is an opening at the center of the iris whose diameter varies from about 1 to 8mm in response to illumination changes, dilating in low light to increase the amount of energy that reaches the retina and contracting in normal lighting conditions to limit the amount of image blurring due to spherical aberration in the eye.

The refracting power (reciprocal of the focal length) of the eye is in large part, an effect of refraction at the air-cornea interface, and it is fine tuned by deformations of the crystalline lens that accommodates to bring objects into sharp focus. The retina itself is a thin, layered membrane populated by two types of photoreceptors-rods and cones that respond to light in the 330 to 730 nm wavelength range.

There are three types of cones with different spectral sensitivities, and these play a key role in the perception of color.
There are about 100 million rods and 5 million cones in human eye. And finally the retina where the image is formed [2].

1-2-1 Effects of age:

Eye disorders among the elderly are a major health problem, with advancing age the normal function of eye tissue decreases and there is an increased incidence of ocular pathology. The most common causes of age related eye disorders and visual impairment in the elderly are Cataracts, Iridocyclitis and Corneal Haze. Iridocyclitis is an inflammation of the iris (the colored part of the eye), while Corneal Haze is a complication of refractive surgery characterized by the cloudiness of the normally clear cornea.

The ability of human eye to focus on nearby and distant objects, attributed to the crystalline lens, is most prominent in children. Changing the shape of the lens is accomplished by rather complicated system of ligaments and muscles. Due to tension in the lens capsule, the crystalline lens, if completely free, would tend to become spherical in shape. Surrounding the edge of the lens is an annular ring called the ***sciliary muscle***, which on contracting squeezes the lens, causing it to bulge. In effect this reduces the focal length of the lens, bringing nearby objects to a sharp focus on the retina.

If the sciliary muscle relaxes, the ***suspensory ligaments*** pull outward on the lens periphery, causing it to flatten. This increases the focal length, bringing distant objects to focus on the retina. This ability is part of the process of vision called ***accommodation.***

As a person grows older, the crystalline lens becomes harder and harder, and the muscles that control its shape grow weaker and weaker, thus making accommodation more and more difficult. This condition is referred to as ***presbyopia.*** When the length of the eye ball is such that incident parallel light rays converge to a point behind the retina. The person is far-sighted and is said to have hypermetropia . When parallel rays come to focus in front of the retina. The person is near-sighted and is said to have ***myopia.***

In order to correct these defects in one vision, a converging lens of the appropriate focal length is placed in front of the ***hypermetropic*** eye, and a diverging lens is placed in front of ***myopic*** eye. A diverging lens in front of the ***myopic*** eye can bring distant objects to a sharp focus [3].

1-2-2 Effects of Aberrations:

The cornea and the crystalline lens are the major refractive components in the eye, and aberrations of the individual components are expected to contribute to overall image quality.

It has been shown that at least for young eyes, a proportion of the corneal aberrations are compensated by aberrations of the crystalline lens. A partial compensation of corneal astigmatism by the crystalline lens was well known in the clinical optometry literature. Also, the fact that the spherical aberration of the cornea is typically positive, while the spherical aberration of the crystalline lens tends to be negative.

Interestingly, a partial compensation of asymmetrical aberrations, such as coma, also seems to occur, at least in young, low myopic eyes.
Several models have been attempted to explain the interactions of corneal and internal aberrations. However, simple tilts and decent rations of the ocular components are not sufficient to explain the complex structure of the total wave aberration pattern[4].

1-3 Modulation transfer function (MTF)

With growing role played by optical device in many applications, there is clear need for characterizing optical components. A basic and useful parameter, especially for imaging systems, is the Modulation Transfer Function (MTF).
MTF is a highly useful parameter in evaluating the performance of an optical system. It is a widely used tool in the design and measurement of optical imaging systems. MTF is one method of evaluating optical system performance based on the contrast ratio. MTF indicates how well the optical system can reproduce a likeness of a subject on the output image. It is expressed as frequency characteristics.

For optics, the frequency is expressed as a spatial frequency, which is the number of lines per centimeter. Normally, a low spatial frequency indicates good contrast and a high spatial frequency indicates good resolving power [5] .

1-4 Aim of the thesis:-

the quality of images produced by human eye (as imaging system) affected by many factors and variables. These variables can create confusion and poor seeing. The aim of this work is to study the effect of some parameters and distortion, that effect the quality of human eye images. These variables include:-

1. Age

2. Pigmentation

3. Aberrations

4. Pupil size

1-5 Literature Review of MTF

The work on (MTF) was started in the 1940s and 50s. In the ten years that followed many practical methods were worked out and were described in the literature [7].

After the development of Duffieux's theory Hopkins [9], the Fourier treatment of the performance of optical systems have been widely studied and the measuring methods of OTF have been extensively investigated.

In contrast to the input output approach of Schade, Hopkins [9] based his (MTF) development on physical optics to provide a comprehensive. Foundation for optical design and evaluation.

Neill [10] assembled his work in a mathematical form particularly appealing to engineers and others familiar with communication theory as applied in electronics system.

Since the amplitude part of the (OTF) called the modulation transfer function is based on measuring the contrast in the image of a periodic object, relatively simple concept, electronics engineers found that is parallel other transfer functions in their expertness so closely that they had no hesitation in applying it to their own instrument. During the 1960s, lenses for low- light level television, microfiche storage and microcircuit application called for the development of a reproducible, objective, and reliable method of specifying and measuring image quality. Adjusting the (OTF) and (amplitude value of (OTF), the (MTF)) art to practice could hardly have been achieved without the modern electronic calculator.

The1970s appear to have been a decade in which modulation transfer function received general acceptance for optical performance evaluation acceptance was helped be the vacuum that was left when limiting resolution was discredited as a comprehensive indicator of optical image properties at the beginning of the decade.

Duffieux [8] showed that the Abbe theory of image formation of coherently illuminated objects may be usefully restated in term of Fourier analysis. He also established the complementary fundamental theorem for the image formulation of self-luminous, incoherent object. The fractional contrast reduction of Fourier component can be called the transfer function of the optical system; Duffieux found that this function depended on both the lens aperture and aberration.

Duffieux [8] demonstrate a new concept of image formation passed largely un noticed by workers in the field of optics, many of whom were concentrating on making consistent measurement of resolving power that would correlate in some way with the predication of lens designers.

An engineer can accomplish a large part of the data processing with a hand – held programmable calculator. However, the amount of data to be processed in typical (MTF) calculations is still great enough to require computer time; in fact, in some instance compromises have to be made between time and accuracy thus, the appearance of the Cooley tukey algorithm and subsequent fast and fast-fast procedure for calculating the Fourier transform and autocorrelation were particularly timely for extensive application of the modulation transfer function during the 1960s.

Chou and Sung [6], described the transfer function of eye using Westhemers line spread function. Dose has not taken into account certain differences between observers, like age and pupil size that can cause the function to vary. Peter Chou and Sophia Sung in this work implemented the Ijspeert et al modulation transfer function. It should be emphasized that these functions were not derived from physical considerations but from curve fitting to experimental data. Thus, the validity of these functions is limited to the range of experimental data available.

Williams [11] showed that two items are required for defining the MTF:

1. A measure of the spatial detail, called frequency.
2. A fundamental measure for determining how that detail is preserved, called modulation transfer.

1-6 Thesis organization

The thesis containing five chapters outlined as follows:-

Chapter two: - describe the theoretical aberration and some functions to describe the image quality in the human eyes.

Chapter three: - describe the human eyes and some diseases and defects in the eye.

Chapter four: - illustrates the results and their discussions.

Chapter five: - includes the conclusions and recommendation for the future

CHAPTER TWO

THE HUMAN EYE

2.1 Introduction

The human eye is a remarkable organ that is linked to our brain. It is incredible how the eye can take all this information, analyze it, and can distinguish between many different shapes, sizes, depths, contrasts, distances, colors and brightness. we depend on our eyes very much in our every day life, and we seem to take them and our vision for granted. Some people do not understand how they work or what it takes to make them function correctly. We shall go into detail to help explain how the eyes work and how they change as we age. The major physical structures of the eye are the cornea, lens, iris, vitreous, and retina[12].

2.2 Anatomy of human eye

The transparent cornea is in the front of the eye. Light is admitted to the interior of the eye through this five layered membrane. The cornea provides the refraction. Refraction refers to bending of light waves that occurs at the surface of a transparent object. The index of refraction determines how much light bends upon entering or leaving a certain material. If no refraction takes place, the index of refraction is equal to 1, but as the light enter the eye the index of refraction changes to 1.336. The light then bends the cornea, lens, and some fluids act together as a converging lens to form real, inverted images on the retina. The outer surface of the cornea mainly doses the focusing of light rays. The greatest change in the refractive index from air to cornea occurs here. The ability to alter the direction of light ray is determined by the strength of the lens. This strength is measured in diopters which is the reciprocal of the focal length measured in meters. [12]

$$D = \text{strength (in diopters)} = 1/f \text{ (diopters)} \qquad (2.1)$$

A young adult relaxed eye has the total power of +60 diopters, in all the transparent materials and +20 diopters in the relaxed lens. The aqueous humor is a clear fluid filled chamber that is behind the cornea. The lenses are layers of transparent fibers that are flattened spheres and are located on the behind the aqueous humor. Ligaments connect the ciliary's muscle to the lens. The lens is somewhat flexible which allows the ciliary's muscles to adjust the diopters power from +20 to+24. This allows focusing of objects at different distances; this adjustable focus is called accommodation. The ciliary's muscle varies the thickness of the lens, this changes the focal length. When the muscle relaxes, it makes the lens thinner, when the muscle contracts the lens becomes more rounded and thicker. Our eyes are similar to that of a simple camera. Our lens of the eye forms an inverted image of objects in front of it on the sensitive retina.

Behind the cornea in front of the lens is the iris, which has a circular opening in its center. This opening is the pupil which is controlled by muscles that are around its edge. When the muscles contract or relax, this makes the pupil larger
or smaller which is turn will control amount of light that is admitted to the eye. A small aperture provides a larger depth of field. This is controlled largely by the autonomic nervous system. The main body of the lens is filled with the vitreous humor. This is a transparent, jellylike substance.

The eyeball is distended of the pressure of the vitreous humor. Floaters within the vitreous sometimes obscure vision. They consist of clumps of gel or cells. These objects appear to be in front of your eye but they are actually floating inside. You are actually seeing shadows they cast on the retina.

The layer closest to the vitreous humor is the retina. Photoreceptors, neural circuitry, and blood vessels at the back of the eye make up the retina. This neural layer called the retina converts light energy into nerve impulses. There are over 120 million Photoreceptor cells in the retina called rods and cones. In the center of the macula lute is the fovea centralis. There is a sensory layer at the center of the fovea which is composed entirely of cone-shaped cells. The cones are nerve cells that help to determine fine detail and are involved in color vision. In the center of the retina is the macula, which is packed with millions of cones. It is because of the macula that we can see clearly and with detailed vision. There are three different pigments in cones. They respond to red, blue, or green wavelength of light. The cones produce the variety of color we see by mixing the color singles.

If a person is color-blind, he/she is missing one or more of the pigments and he/she has trouble distinguishing between certain colors. The rods determine the shape of an object and also allow you to see in dim lighting. Rods also provide peripheral vision and are insensitive to color. Where the resolution is greatest in the fovea, each cone has a direct path to the optic nerve.

The light rays that reflect on the lower half of an object we are looking at will focus on the upper half of the retina. The rays reflecting on the upper half of the same object will focus on the lower half of the retina.

When the brain processes the information the signals are rearranged into an image that is right side up. Three things must happen when we look at something. The image must be reduced in size so that it will fit onto the retina. The scattered light must come together, in other words it must focus at the surface of the retina and the curve of the retina must match the curve of the image. What accomplishes this is the lens between the retina and the pupil and the cornea. The lens which is classified as a plus or converging lens because it is thicker in the center, and the cornea work together to focus an image on the retina [12].

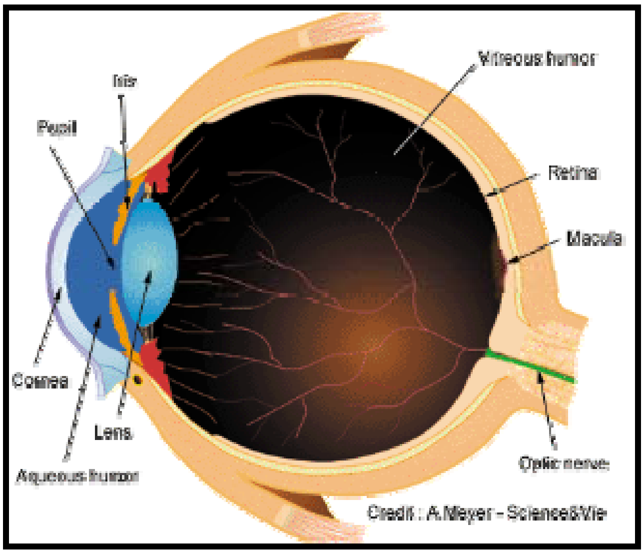


Figure (2.1) show the human eye [13]

But sometimes the eye just dose not focuses quite right. The eye not being able to focus the image onto the retina is the most common type of the vision problem. One common problem is Myopia, which is also called nearsightedness or short sightedness. A person with nearsightedness can see things up close but not at a distance. Nearsightedness is when the light rays become focused in front of the retina and the image being formed of a distant object look blurred. The reason for this might be the eye is too long, the cornea and the lens converge the light rays too much, or the ciliary's Muscles do not relax enough so the lens is too thick. The corrective lens for nearsightedness is a diverging or concaved lens. The image is being formed in front of the retina, so the diverging lens diverge rays so that they can be converged again correctly by the eye lens and cornea onto the retina.

When hyperopic, farsightedness or long sightedness happens a person is able to see objects at a distance but has a problem with seeing objects up close. In farsightedness the light rays do not converge enough to form an image on the retina so the light rays become focused behind the retina. A few reasons for this are the eyeball is too short, the cornea and lens do not converge the light rays enough, or the ciliary's muscles do not contract enough making the lens too thin. The corrective lens for farsightedness is a converging or convex lens, which helps the lens and the cornea converge the light rays, so the image is focused onto the retina.

Presbyopia is a common visual condition. Presbyopia is when you get older and your lenses harden and become less elastic. Your lenses inability to change shape and focus light passing through the eye is due to this hardening of the lens. Presbyopia is more noticeable when we try to focus on things up close. The loss of elasticity prevents the lens from becoming thicker. Presbyopia makes more your eye lens behave much like that of a camera that has a fixed focus. This camera can take pictures of objects at a distance that are clear but when you take pictures of objects up close they turn out dim and blurry.

Another common focusing problem is astigmatism. This is when the corneas curvature is uneven and will cause a distorted vision. To correct this problem, a lens is shaped to correct the unevenness. You can see how the eye is an amazing organ that is very important for our every day life. There are many structures in the eye that all work together to give you vision. Many of the common focusing problems such as farsightedness, nearsightedness and astigmatism can be corrected by different lens.

2.3 How does the eye works:

The light emitted or reflected by an object we are looking at enters the eye through the cornea. The light rays then pass through the pupil (which regulates the amount of light entering the eye) and then cross the (crystalline) lens.

Finally, the light rays are focused on the retina which is a thin layer covered with light receptor cells. Thanks to electrochemical reaction, the light is converted into electrical impulses transmitted to the brain by the optic nerve. About at the center of the retina is a small depression known as the macula. At the center of the macula, in an area called fovea, cells are densely packed and provide the sharpest colored and most detailed information. But, despite the importance of the fovea, the other parts of the retina are also very useful to detect motion, to see in dim light.

From an optical point of view, the eye may be compared to a camera. On the one hand, the lens combination of the camera forms an image on the sensitive film and on the other hand, the eye forms an image on the retina. An eye is said to be normal or emmetropic if the image of a distant falls on the retina, otherwise the eye is said to be ammetropic.

But the normal eye is also able to see near object, thanks to a fine focus (Crystalline) lens gives a variable focal length to the eye. With this accommodation mechanism, the normal young human eye is able to see near objects, say 25 cm in front of him.

In this way, the human eye may be more precisely compared to an auto focus camera, adjusting continuously in order to bring the image into focus.

But with age, accommodation begins to fail and the image of near objects can't be focused on the retina.

This phenomenon is known as Presbyopia and begins to affect people at the age of 40. To understand how diabetes affects the eye it is important to know how the normal eye functions. The eye works very much like a camera, with a focusing lens in front and the film in the back. In the eye, the retina plays the role of a camera s film, receiving image of the object at which the camera is focused. The retina, which is actually a direct extension of brain tissue, transmits the visual information through the optic nerve to areas of the brain which processes it into vision. In a camera, no matter how clear or strong the lens and how perfectly focused the image may be, if the film is not working well the camera will not take good pictures. Similarly in the eye, if the retina is diseased vision will be impaired no matter how clear and strong the lens may be. Furthermore, if the space between the lens and the retina is obscured with blood or other material, vision will be impaired [14].

2.4 Some diseases are due in the human eyes:

There are some diseases are due in human eyes caused problem in the view of eye, in this chapter take some of these defects for studying.

2.4.1 Astigmatism:

Is the optical condition where the refraction is change at the different axis of the eye such that there is no focus at the retina? We can classify the astigmatism according to the defects in biological construction of the eye: (fig.2-2)

1. Curvature Astigmatism: which it is most popular kind of Astigmatism which is happens as a result of anomaly of cornea curvature or lens curvature.
2. Astigmatism resultant from the anomaly of lent icons.

3. Index Astigmatism: Astigmatism may be appear as a fewer percent as a result of non-equality of the refractive index of the lens, sectors.

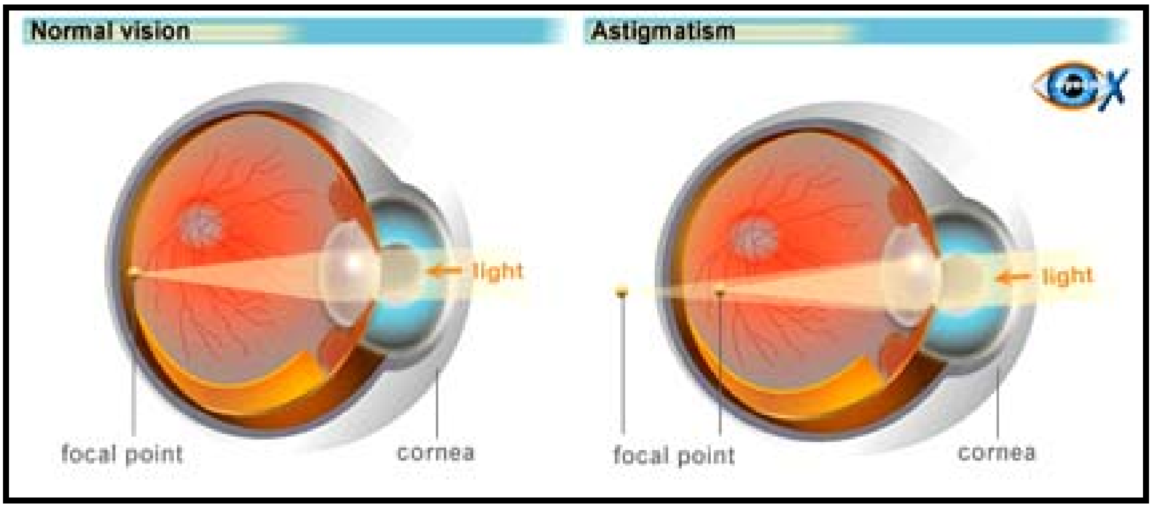


Figure (2-2) represents normal and astigmatism vision [15]

And the Astigmatism's ***Symptomology*** is***:***

Theoretically there non eyes having no Astigmatism because the curvature of the vertical cornea axis which is natural physiological phenomena are called Astigmatism with the rule. When the person became older this phenomena either vanishing or reversing to the Astigmatism against the rule. The most popular reason of Astigmatism against the rule is aphakia where the vertical cornea axis becomes more surfacing as a result of surgical wound [16].

2.4.2 Hypermetropia (Long sightedness)

We can define Hypermetropia as the error in reflection where the incoming parallel light beams from the infinity gathered behind the retina with the limited distance when the eye is relived. Figure (2-3) there are many organic causes which generate hypermetropia as follows:

1. axial hypermetropia : most of hypermetropia are the axial hypermetropia which is shortage in the Antro-posterior axis of the eye which is the most popular error in refraction and represents stage of the normal development on birth all eyes are almost hypermetropia to (2.5-3) diopters, and when the body is going to grow the Antro-posterior axis of the eye is going to lengthen extremely to the adolescence where the eye theoretically must be emmetropic but actually, there are 50% of the persons who have hypermetropia cannot reach the emmetropic where part of hypermetropia is found. From other side the Antro-posterior axis may be continuing in lengthen until the eye became myopic. The eye must be represented as emmetropic in stage of the normal development of eye. From the biological side the hypermetropia in the children it represents a stop point of the incomplete development of eye. As general rule the grade of shortness is not big and rarely over (2mm), and each 1mm of shortness approximately equal 3 diopters of the eye changes of refraction, so that the hypermetropia more than 6 diopters is not common.

The high grades which appear and reach to 24 diopters may be back to the other pathological anomaly. The shortness of Antro-posterior may be appearing as pathological anomaly, orbital tumor or inflammatory mass may be effect on the posterior pole of the eye. Intraocular neoplasm may be displacing the retina to the macular region, and most circumstances may be causes by detached retina which displaced to touch the back surface of lens.

2. Curvature hypermetropia: is appearing when the curvature of each refractive surface is small. Cornea is the actual place of irregularities and may be surfacing congenitally aftermath of the diseases or tumor.

The increases about 1mm in radius of curvature of cornea generate hypermetropia about 6 diopters.

3. index hypermetropia: this kind of hypermetropia appear because the decreases of the active reflective ability of the lens which is responsible for hypermetropia which is appear as the age is progress, so is appear in the persons who have diabetics under treatment.
4. Dislocation back wards of the lens: this causes the hypermetropic which appears as anomaly of birth or case of disease.
5. Aphakia; is a case of absence of lens from the eye rather from surgery or from gashing breaking through the lens or as a reason of congenital defect. The eye with aphakia has a strongly hypermetropic, and if the eye is emmetropic the eye is substitute with strong convergence lens (+10D) [17].

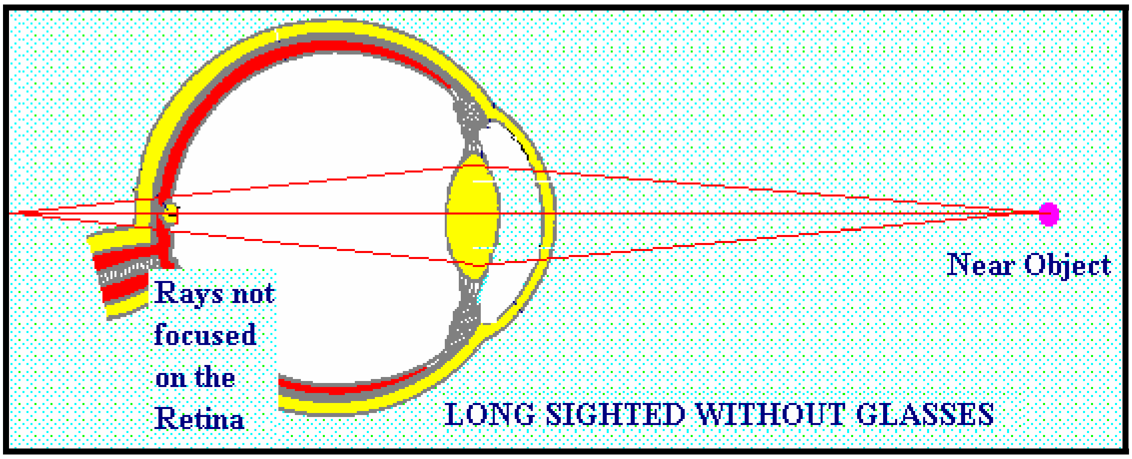


Figure (2-3) represent long sighted in human eyes [18]

3.4.3 Myopia (short sightedness):

Are the refractive circumstances which happen in the eye where the incoming parallel light beams from the infinity gathered in front of the retina when the eye is at rest. The term myopia or short sightedness comes from the habit where the persons who have it try to shut their eyelid with half shut when they looking to the far objects to try to collect the light beam and focusing it on the retina to get clear image, so this just like making a pin hole. Figure (2-4).

The Aeatology of organic structure which are cause myopia are:-

1. Axial myopia: this is the most popular kind of myopia because of simple physiology change in the length of eye.
2. Curvature myopia: which is happen because the increasing the radius of curvature of the cornea or the lens, like kerato-conus or lensconus.
3. Index myopia: this is happen because the increasing of the refractive index of the lens or of the refractive surfaces of the eye, like the increasing of the refractive index of the lens in nuclear cataraet and Diabetes.
4. Abnormal position of lens forward.

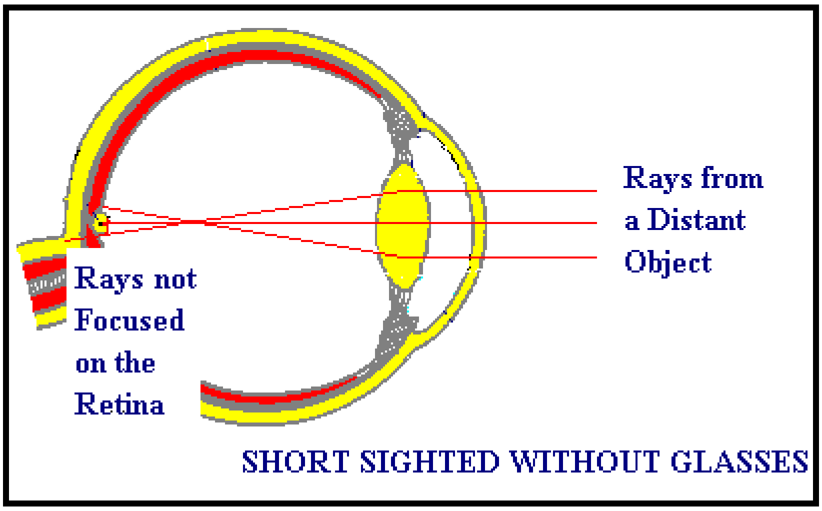


Figure (2-4) represent short sighted
in human eyes [19]

and the ***Myopia's Symptomatology is*** :

The parallel beam comes too gathered in front of the retina so the circle of diffusion will form blurred image for the visible objects. The accommodation make the blurry be the seamier instead of to be better, so the patient who has myopia need to accommodation effort fewer than the normal person or the person who has hypermetropia [20] .

CHAPTER THREE

THEORETICAL BACKGROUND

3.1 Introduction

The performance of any imaging system (such as camera, human eye,…) is based on its ability to produce images with certain quality. There are two types of measurs that are used in image quality measurment these are objective (quantitive) and subjective (qualitive). This chapter discuss some criteria that used for image quality measurment and optical distortions in an optical system. The key components of image quality are resolution, contrast and distortion.

3.2 Resolution and Resolving power

Resolving power is measure of imaging system to produce detectably separate images of objects that are close together.

Resolution is a measure of an imaging system's ability to reproduce object detail. Or it is defined as the ability to distinguish between two closely object on an image.i.e Resolving power applies to an imaging system, while the resolution applies to the quality of produced images by the imaging system.

Resolving power and resolution are defined as the number of line per unit distance (mm) that is just resolved by the human eye looking at standard resolution chart of standard contrast and illumination.

3.3 Contrast

Contrast is a measure of difference in brightness or optical density in adjacent regions of the image. The contrast can be defined as: [22]

$$Contrast = \frac{B\max}{B\min}$$

where B is brightness.

Contrast also contribute to image quality because it express how well an image can differentiates between an object's shades of gray.

To understand the close relation between resolution and contrast, we think of imaging a target of black and white lines (fig.3.1.a). The contrast of this target represent 100%, but the transformed contrast information will be less than the original contrast even for perfect imaging system this is due to the diffraction limit and distortion in lens. As the spatial frequency increases (width of line decreases) the imaging system is less able to transfer the contrast, so the resulting image have less contrast.(fig.3.1.b).

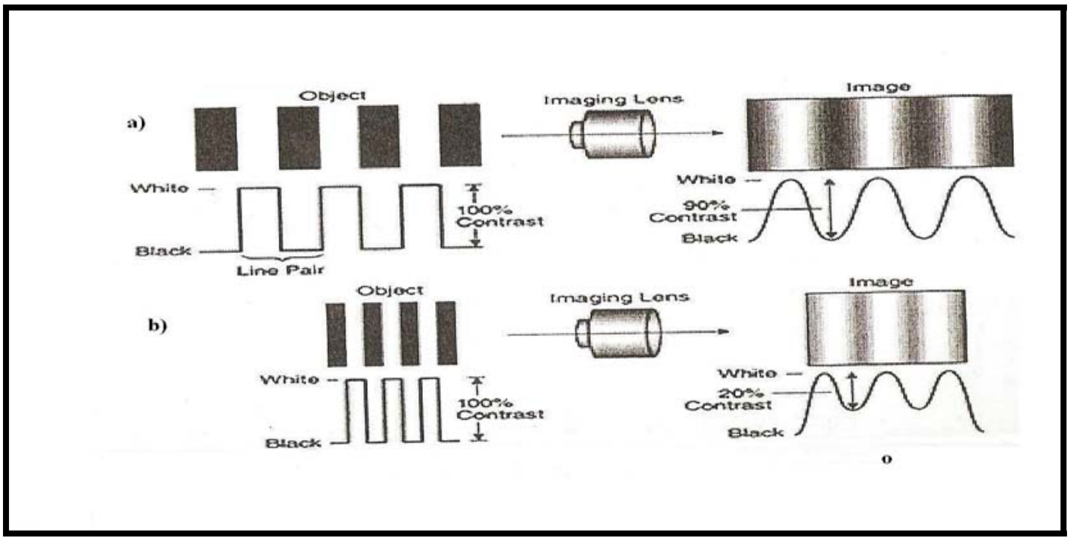


Figure (3.1) at increasing spatial frequencies, optical information passing throgh a lens losses contrast. (a) the 100% contrast information becomes 90% contrast.
(b) the higher-frequency information that stars at 100% contrast becomes 20% contrast after passing through the same lens [23]

3.4 Point Spread Function :-(PSF)

PSF is a classical measure of imaging system performance. PSF charactrize the imaging performance of an optical system in its image plane for a point object.

Theortically, point source of light produces sharp defined edge image.(fig.3.2) [23]. If the imaging system is not ideal, the resolution of a point source image would be degraded .

The image of a point source in an ideal imaging device is give as:

$$f = \pi D^2 J_1{}^2 / \lambda^2 \qquad (3.1)$$

where f= light intensity

D = diameter of imaging system aperature

λ = wavelength of light

J_1= Bessel function of the 1st order

Image equation for the image f(α) of an object g(α) can be written as a convolution as :

$$f(\alpha)= g(\alpha)*o \qquad (3.2)$$

where (o) is the point spread function (PSF)

3.5 Optical Transfer Function(OTF)

The optical transfer function (OTF) of an optical system tell how the orginal contrast has been maped in an image. OTF is a complete measure of system performance, it includes the phase and amplitude degradiation of the image as the spatial frequency change. The OTF is the fourier transform of the (PSF). So, by applying (FT) at the imaging equation (3.2) ,the out put equation will be [24]:

$$F(\upsilon) = G(\upsilon) . O(\upsilon) \qquad (3.3)$$

Where (υ) is spatial frequency, O(υ) is (OTF). It is worth to mention that the modulus of (OTF) is Modulation Transfer Function (MTF).

3.6 Modulation Transfer Function (MTF):-

One of the most important parameters for the description of the quality of an optical image is the modulation transfer function (MTF). It describes how an object function is transferred by a lens system into an appropriate image. MTF is a highly useful parameter in evaluating the performance of an optical system. It is a widely used tool in design and measurement of optical imaging systems. The amount and quality information depends on whether the object is surrounded by a dark or light background ,contrast, the size of the object, spatial frequency, and the quality of the optical system. The (MTF) determine the amount of fine detail that will be observed by an optical system. Also it is one method of evaluting optical system performance based on contrast ratio. MTF indicates how well the imaging system can produce a likeness of a subject on the output image. It is expressed as spatial frequency characteristics (number of line per mm). low spatial frequency indicate good contrast and high spatial frequency indicates good resolving power.

Any imaging system acts as low pass filter so, when imaged with lens the actual pattern observed with a gradual decreasing intensity rather than a clear boundary as it is shown in figure (3.3). The ratios of the Modulation in the image to that of object then will be a measure of how well the image is formed for that particular frequency. The ratio is called MTF ratio that is [23]

MTF= Modulation of image / Modulation of object

Modulation of image (MI) = Imax-Imin / Imax+ Imin (3.4)

Modulation of object (Mo)= Imax –Imin / Imax + Imin (3.5)

MTF =MI / Mo (3.6)

Figure (3.3) a sinusodial intensity pattern
as input for MTF mesurment [23]

3.7 MTF Curve :-

When MTF measurment is made over a range of spatial frequency, it is possible to plot a curve of MTF with frequency. MTF curve indicate how much the imaging system (lens system) reduce the contrast. The horizontal axis of this curve represent spatial frequency in mm^{-1} and the vertical axis is MTF (contrast). As shown in figure (3.4). The higher the MTF, the higher contrast and resolution. With value 1 (or 100%) on the MTF curve indicating zero reduction (which is impossible) of contrast [23].

The modulation transfer function may be used to describe the optical quality of the eye by giving the amplitude response of the system to different spatial frequencies. The blurring caused by the optics of the eye causes the amplitude to be reduced as spatial frequency increases.

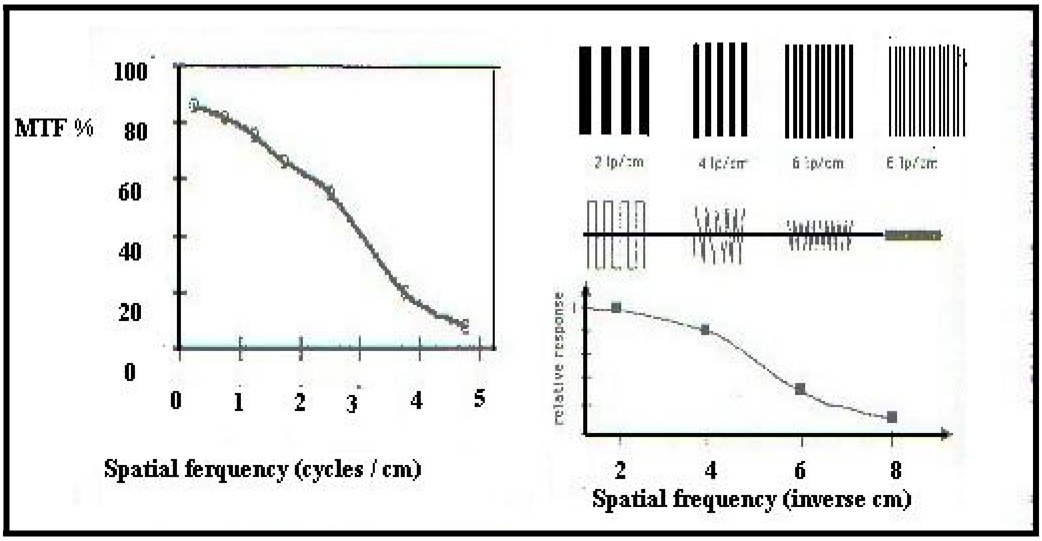


Figure (3.4) Typical MTF as a function of Spatial frequency [23]

3.8 lens Aberrations:

If a point object can be projected into a point image, the system is said to be "diffraction limited". But there are other limitations besides diffraction that prevent an object from being a true likeness of the object. These are called aberrations. Some of them are known as regular, other are irregular. Aberrations become more serious if the lens has a large aperature.

In general, the aberration can be defined as the departure or deviations from the laws of paraxial image formation [25], or it may be defined as, the breakdown of accurate correspondence between points in the object plane and the same points in the image plane. Aberrations occur in all practical image-forming systems. Some aberrations are the result of balancing during design, others are intrinsic to a particular image formation system and some are introduced as the result of fabrication of an actual system [26]. The type and form of these aberrations can be related to the constructional parameters of the system and can be calculated by the process of ray tracing or by analytic formulae.

For ideal lens, every ray of light from any given point on the object would cross at exactly the same point on the image. Further, the image would be similar to the object in every respect. Any regular shape (circle, square…etc) on the object would be a perfect (circle,square….etc) on the image. If the objects were all in one plane, the image would be all in one plane.

Actually no such ideal lens exists. For a single lens, the rays from point on object ordinary fall over a small region of the image. If most of the rays from a point on the object cross at the desired image point but some of them cross off on one side, a linear defect occurs, such as coma, spherical…etc. Also, there is a non-linear distoration occurs with some lenses, so the image of a rectangular object may look like a barrel or in other cases a pincushion shaped. Within geometric raytrace optics, a perfect optical system is stigmatic, meaning each object point focuses to a single image point. Wavefronts diverging from an object point are always spherical. After being transformed by a stigmatic optical system, converging wavefronts are again sphereical, but are now centered on the image point. An aberration is any departure from sphericaly or shift in centration of a converging wavefront leading to blurred or systemically moved image points. The types of aberrations can be generally classified in those that cause a local shift of image points (distortion), and those that cause blurring (such as spherical aberration, curvature of field, astigmatism coma, etc). .

The traditional description of an aberration is as defect, or error in the position of a ray intersection relative to a specified reference coordinate in the image surface, or as optical path difference measured from a reference shpere located in the exit pupil of an optical system. The aberration is traditionally expressed in terms of coefficients of a power series in the exit pupil coordinates. There are two basic types of aberrations; monochromatic aberrations and chromatic aberrations see figure (3.5).

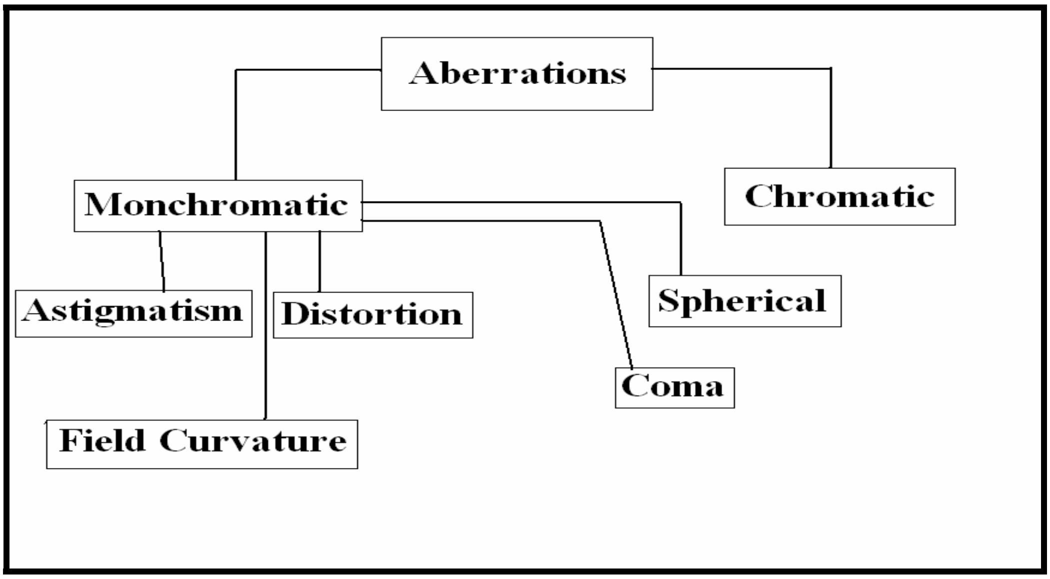


Figure (3.5) Types of aberration

3.8.1 Chromatic Aberrations

chromatic aberration is caused by a difference in light wavelength. The focal length and magnification of a lens varies according to the wavelength of each color of incident light see figure (3.6 (a) and (b)) . Accordingly, if we look at an image through a lens with chromatic aberration, the higher the magnification, the bigger the chromatic aberration.

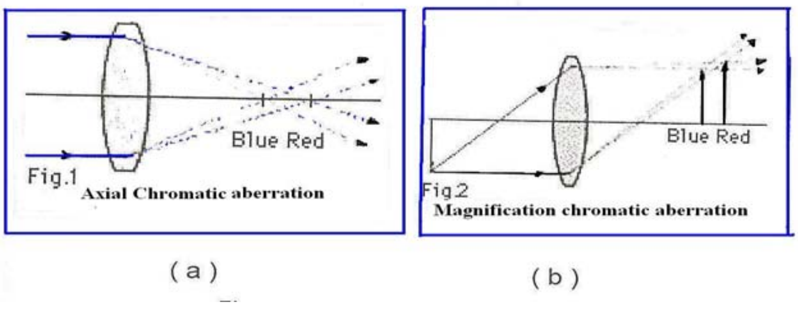


Figure (3.6) chromatic aberration [27]

3.8.2 Monochromatic Aberrations:

Monochromatic Aberrations, which is defined as deviations from ideal optics, is also called the primary or Sedel aberrations set [28]. These aberrations include :

1. Spherical aberration
2. Coma
3. Astigmatism
4. Field curvature
5. Distortion

The effect of these aberrations generally includes image defocus and image shift.

3.9 Power Series Representation of Primary Aberrations

Consider a general ray from an object point (σ,τ) passing through the image entrance pupil plane at (x,y). The four variables (σ,τ ;x ,y) completely specify the ray and it is clear that the power series wave aberration associated with this ray must be some smooth function of these four variables.

If we are to expand the wavefront aberration function w (σ,τ ;x ,y) by Taylar's series, then the first few terms would be [29]:

$$W=a_{0000}+a_{1000}\sigma+a_{0100}\tau+a_{0010}x+a_{0001}y+a_{1100}\sigma\tau+a_{1010}\sigma x+a_{0110}\tau x+a_{0101}\tau y+a_{0011}xy+D(3) \quad (3\text{-}7)$$

Where D(3) is the error term due to ommiting the 3^{rd} order and higher terms.

For various resons such polynomial expansions of the wave aberration are very useful and it is a common practice to describe the five primary (or Sidel) aberration,by these terms.

In assuming the object to lie on the $\mathbf{T_{axis}}$,the equation of wave front aberration (w) on the polar coordinate system in term of aperture (r) may be given as [29]:

$$W=w\,(r^2\,,\,T^2,\,\cos\varphi) \qquad (3\text{-}8)$$

Then, the power series expansion of the aberration function takes the following general form:

$$W=\sum_i \sum_j \sum_k a_{ijk}\,(\tau^2\;)^i\,(r^2\,)^j\,(\,r\,\tau\,\cos\varphi\,)^k \qquad (3.9)$$

Where a_{ijk} is the cofficient of aberration,i, j, k (run 0,1,2), between the ray entering in the center of a lens and that entering at the boundary.

We can rewrite the above equation in a notation which is widely used:

$$W=\sum_l \sum_m \sum_n w_{mn}\,\tau^l\;\; r^m\,\cos^n\varphi \qquad (3.10)$$

Where l is the power of τ, m is the power of r, n is the power of cos .

3.9.1 Spherical Aberration

Spherical aberration is defined as any deviation from the light paraxial rays (from point source P in figure 3.7) along the optical axis at the focal point of the paraxial rays (point p in figure 3.7). It can also be defined as the variation of focus with aperature [30]. Therefor, a lens suffering from spherical aberration is not capable of brining rays to a focus in the same plane normal to the optical axis if the distances of these rays from the axis are different. i.e. spherical aberration is the name given to the effect where the focal length of a lens will vary depending on how far is the ray from the center of the lens. What this means in reality is that a parallel ray of light entering the lens near the center of the lens will be focused behind the parallel ray entering near the edges of the lens. The figure below gives a graphic example of the effect. Note that the rays near the edge of the lens refracted more than those near the center.

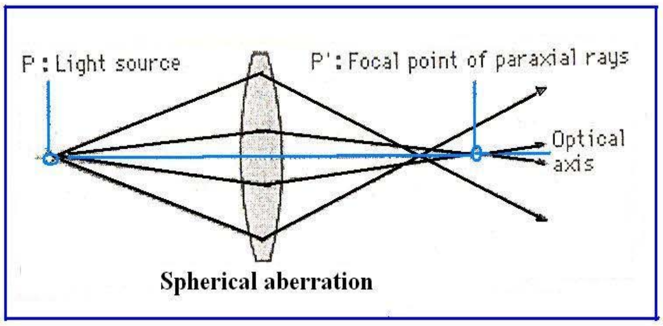


Figure (3.7) graphic example of spherical aberration [30]

3.9.2 Coma Aberration

It can be defined as the variation of magnification of the image with aperature. If an optical system is suffering from coma, the oblique rays passing through the edge will be imaged at height different from those rays passing through the center of the optical system. It applies to rays entering the lens at an angle. The focal point of the lens will vary the further away the ray hits the lens from the center. Due to this we will get blurring of our image the further off-axis we go. A comatic point source image typically has a comet-like appearance, hence the name [30].

Coma is related to spherical aberration, in that the shape of the lens causes both. However, coma is not present in the center of an image but gets progressively worse as we stray from the center (see figure 3.8). Coma aberration is an off-axis asymmetrical aberration; cama aberration cofficient is given as: [30]

$$W = \Sigma\, w_{ml}\, \tau\, r^{m} \cos\Phi = w_{31}\, \tau\, r^{3} \cos\Phi \qquad (3.11)$$

And, by using x-y coordinate system:

$$W = w_{31}\,(x^{2} + y^{2})\,(x \sin\Phi + y \cos\Phi) \qquad (3.12)$$

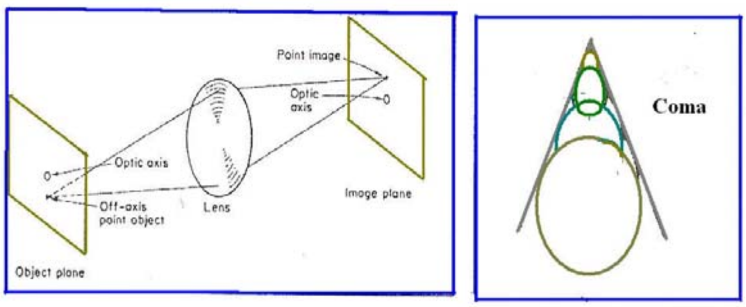


figure (3.8) illustration of coma aberration [30]

3.9.3 Astigmatism Aberration

Like coma, in astigmatism, a source that strays from the optical axis creates rays that get focused in different places. Astigmatism occurs when the lens has different curvatures in different directions (3.9).

Astigmatism is an optical aberration in which a point object is imaged as two longituinally separated and perpendiculariy orinted line segments. The two generators of astigmatism are oblique ray incidence and surface toricity. Optical astigmatism is caused by non-normal or oblique incidence of light, while surface of astigmatism is generated by surface torcity (i.e., the surface curves faster in one direction than another does).

The general form of astigmatism equation is given as [30]:

$$W={}_2w_{22}\,\tau^2\, r^2 \cos^2 \Phi = {}_2w_{22}\,(x^2 \sin^2\Phi + y^2 \cos^2\Phi + xy \sin 2\Phi) \quad (3.13)$$

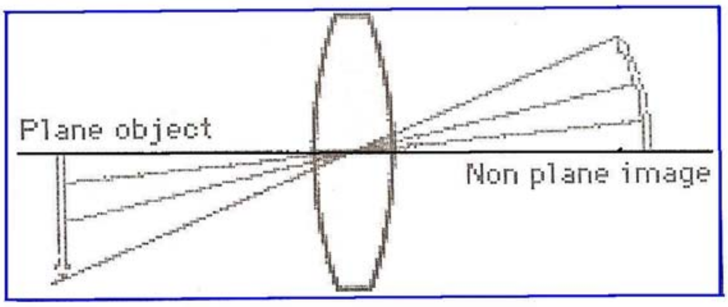


Figure (3.9) Astigmatism and field curvature aberrations

3.9.4 Field Curvature Aberration

Curvature of field is the failure of a lens to transform a plane object into a precisely plane image. For a fixed object position field curvature equals approximate defocus. It is closely related to astigmatism. Both aberrations vary directly with the tangent obliquity and inversely with the square of the focal length. But astigmatism varies with object distance while curvature of field dose not.

For rays entering the lens on or near the optical axis (paraxial rays) the focal length of the lens (barring other aberrations) is constant. This leads to the problem of field curvature. As the distance from the center of the lens to the focus point is constant then the image described by the lens is going to be a curved surface not a flat one. The field curvature coefficient is given by [30]:

$$W= {}_2w_{20} \quad r^2 \ T^2 \qquad (3.14)$$

3.9.5 Distortion Aberration

Distortion, like coma, is not a primary aberration but the result of others aberrations. In distortion we find that the transverse linear magnification in the image varies with the distance from the optic axis. This results in distortions and causes a square object to look like a barrel or a pincushion. Distortion does not effect the resolution of the image; it merely changes the location of image points. The focal length of the lens and hence the magnification it causes varies over the surface of the lens, this leads to distortion. Distortion is where parts of the image are magnified more or less than others.

The most common distortions are barrel distortion (where the center of the image is bigger than the edges) and pincushion distortion (where the edges are bigger than the center). These can commonly be seen on TV's and computer monitors (3.10). The distortion coefficient may be given as [31]:

$$W = {}_3w_{11} \, \tau^3 \, r \ \cos \ \Phi \qquad (3.15)$$

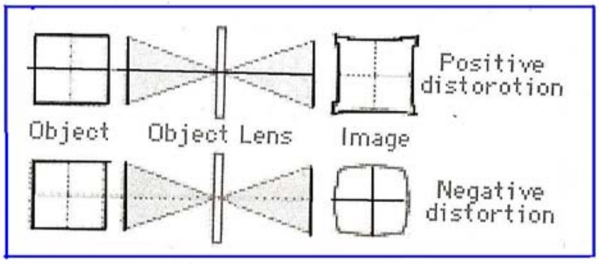


Figure (3.10) positive and negative type of distortion [31]

3.10 Point spread function and MTF of the human eye:-

The objective measurement of the optical quality of the eye is usually performed by delivering light into the eye and recording the light reflected off its fundus.

In particular, the double pass method provides reliable estimates of the modulation transfer function (MTF) [32], but the output beam is conjugated to the input beam canceling phase information .therefore, it is not possible to recover the point spread function (PSF) with the symmetric double-pass (SDP) as it only provides its autocorrelation.

Depending on the balance between diffraction and aberrations determined by pupil size, we obtain the PSF by applying one of two alternative approaches:

1- For large aberrations (large pupils, defocus, off-axis), in this case, the PSF can be estimated directly.

2- When aberrations and diffraction contribute similarly (small to medium size pupils, on-axis), phase information is lost for high frequencies due to diffraction. The PSF can be determied from both magnitude and low-frequency phase information.

GHAPTER FOUR

Practical Work Results and Discussions

4.1 Introduction

This chapter includes two parts, first part study the effect of optical distortion and human parameters on image output, while the second part include Experimental setting work to study the effect of resolution, contrast and age on image quality.

Since imaging systems (eye, lens …) are imperfect, output images represent degraded version of an original image. It is important to understand the nature of the degradation for the image recovery.

1. Optical distortion:

The first part of this work includes the calculation of aberrations effect upon image quality. Computer work using ***MATLAB*** program is carried out to study the effect of optical aberrations on image quality in term of MTF.

A .Spherical aberration

The phase difference $\Theta_{sph}(\zeta , \gamma)$, is given by: [30]

$$(4\text{-}1)\quad \theta_{sph}(\zeta,\gamma) = (Ma^{4})(2\pi \backslash \lambda)$$

Where *M* is the spherical aberration coefficient a is the normalized distance of each point from the center plane, and is given as:

$$a^{2} = \frac{(x-x')^{2} + (y-y')^{2}}{D^{2}} \qquad (4\text{-}2)$$

Where *x', y'* are the coordinates of the pupil function central point.

D = is the pupil radius.

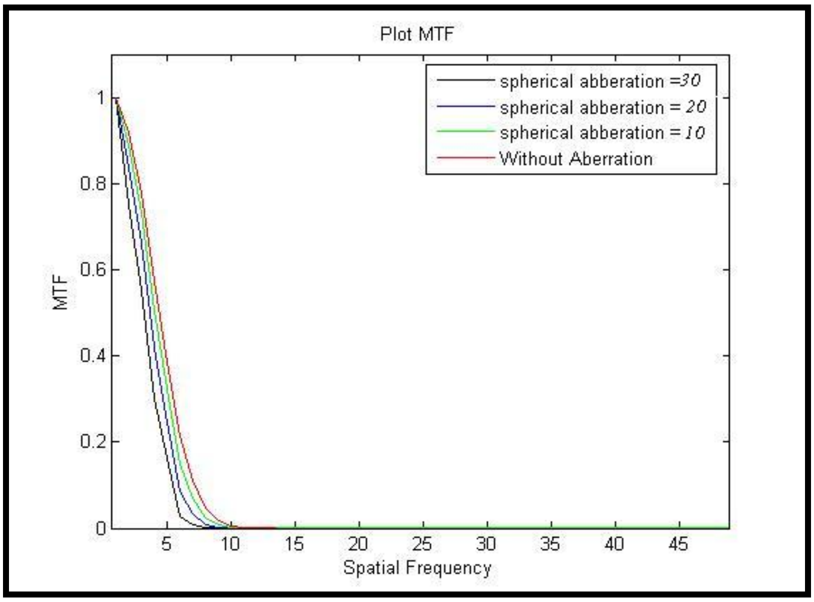


Figure (4.1) shows the MTF with spherical aberration (diameter=4mm, spherical=10, 20, 30)

Figure (4.1) shows the MTF with spherical aberration for pupil diameter 4mm and the value of the spherical aberration coefficient 10, 20, and 30,these values were taken from hospital for patients suffering from spherical aberration. When the degree of this aberration increase the MTF decreases. Figure (4.2) and figure (4.3) also shows this kind of aberration but for pupil diameter 5mm and 6mm respectively.

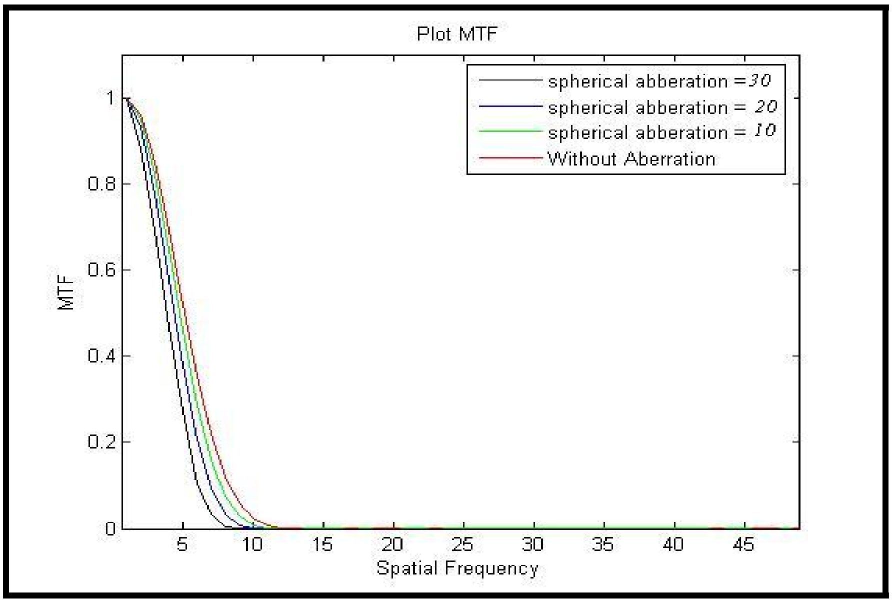


Figure (4.2) shows the MTF with spherical aberration(diameter=5mm, spherical=10, 20, 30)

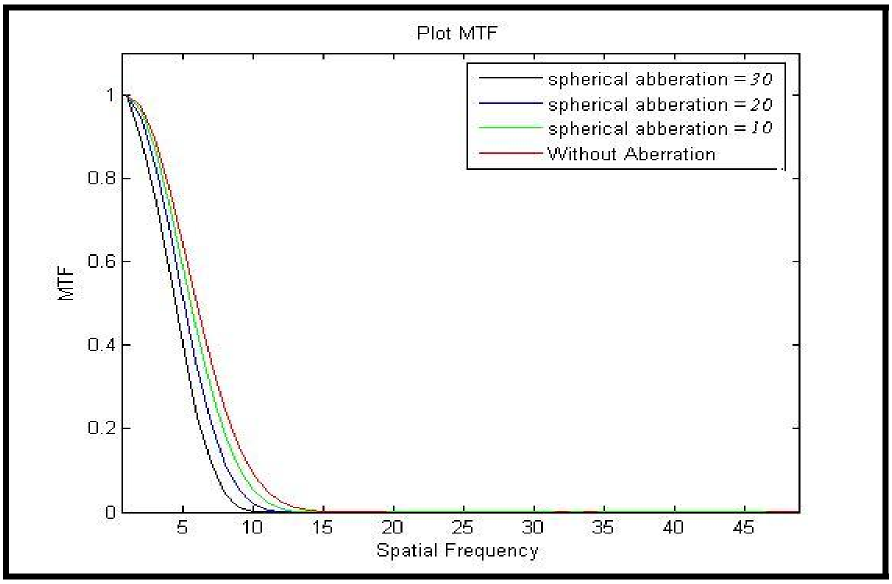


Figure (4.3) shows the MTF with spherical aberration (diameter=6mm, spherical=10, 20, 30)

B. Coma aberration:

The phase difference in the pupil plane can be represented by: [30]

$$\phi_{coma} = (Ma^3 \cos\theta)(2\pi \setminus \lambda) \qquad (4\text{-}3)$$

Where *M is* the coma aberration coefficient, θ is the off axis angle .

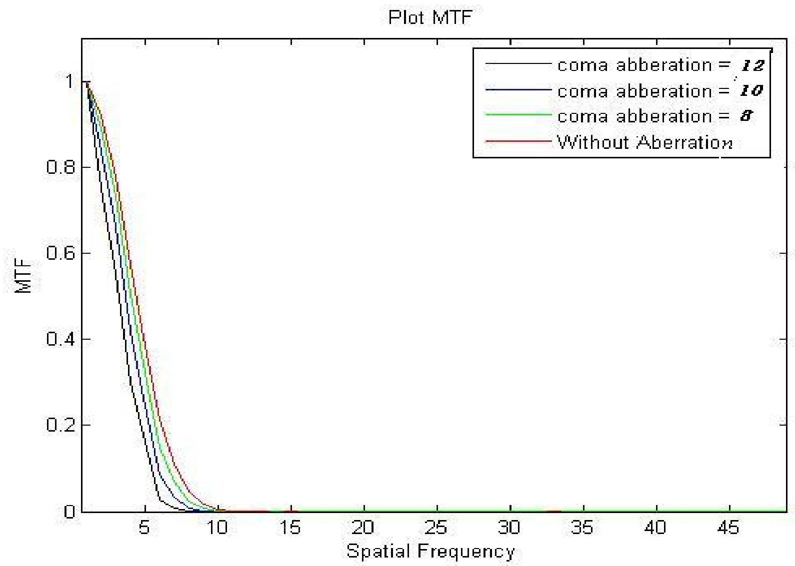


Figure (4.4) shows the MTF with Coma aberration (diameter=4mm, Coma =8,10,12)

Figure (4.4) shows the MTF with Coma aberration for pupil diameter 4mm and values of the coma aberration coefficient 8, 10, and 12, these values were taken from hospital for patients suffering from this kind of aberration. Figure (4.5) and figure (4.6) also show these effect of aberration on the human eye but for pupil diameter 5mm and 6mm respectively.

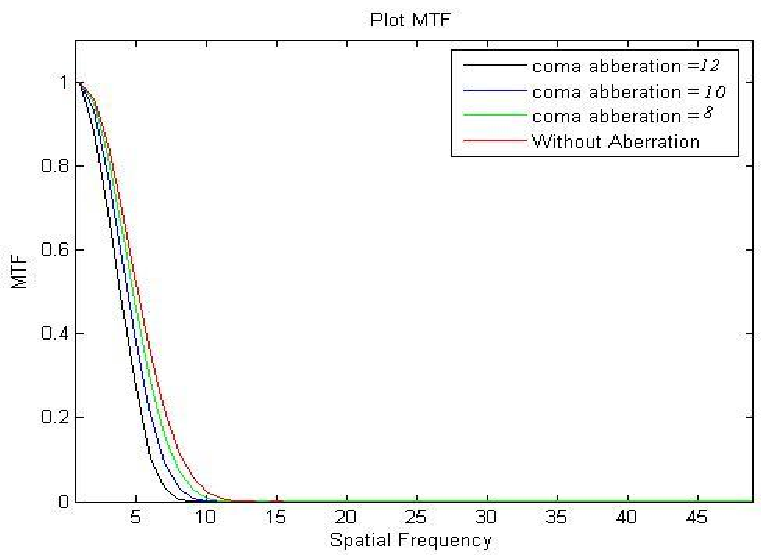


Figure (4.5) shows the MTF with Coma aberration (diameter=5mm,Coma =8,10,12)

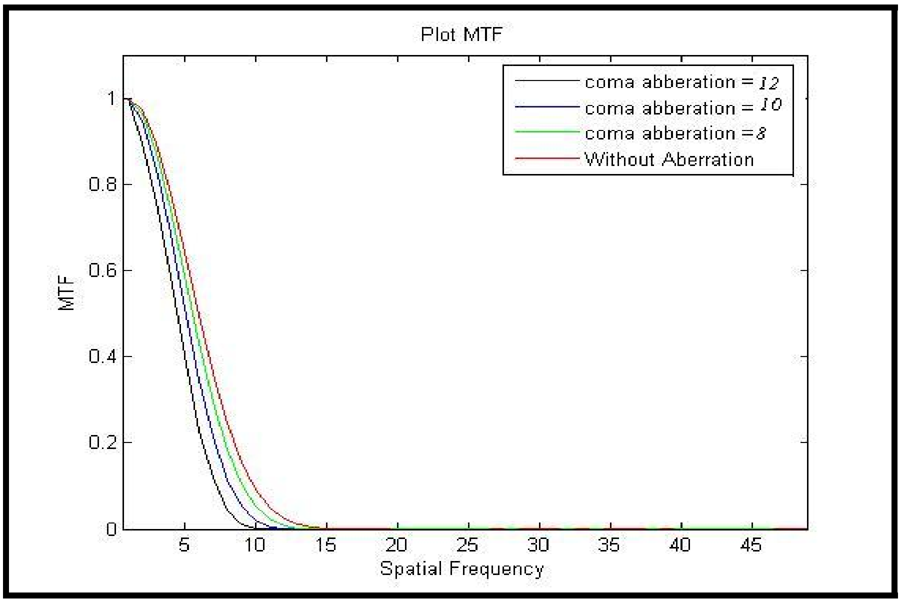


Figure (4.6) shows the MTF with Coma aberration (diameter=6mm, Coma=8,10,12)

C. Astigmatism aberration:

The phase difference in the pupil plane can be represented by: [30]

$$\text{(4-4)}\quad \theta_{ast} = (Ma^2 \cos^2 \theta)(2\pi \setminus \lambda)$$

Where *M is* the astigmatism aberration coefficient.

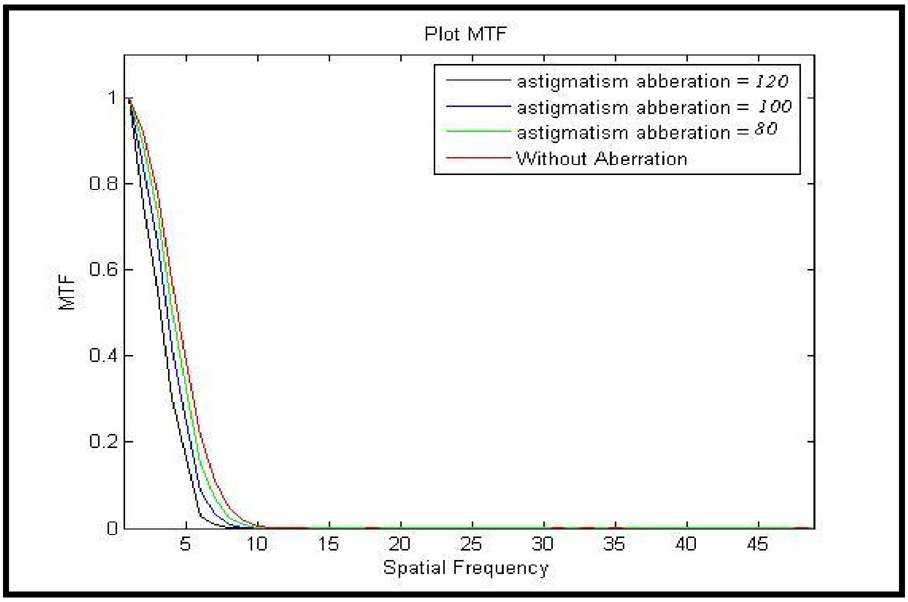


Figure (4.7) shows the MTF with Astigmatism aberration (diameter=4mm, Astigmatism =80,100,120)

Figure (4.7) shows the MTF with astigmatism aberration for pupil diameter 4mm and values of the astigmatism coefficient 80,100 and 120, these values were taken from hospital for patients suffering from this kind of aberration. Figure (4.8) and figure (4.9) also show these effect of aberration on the human eye but for pupil diameter 5mm and 6mm respectively.

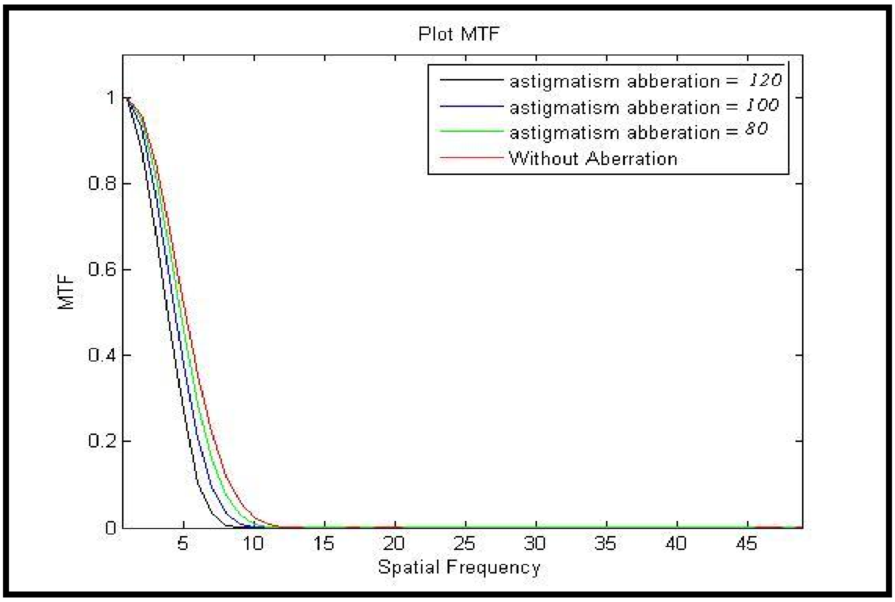


Figure (4.8) shows the MTF with Astigmatism aberration (diameter=5mm, Astigmatism =80,100,120)

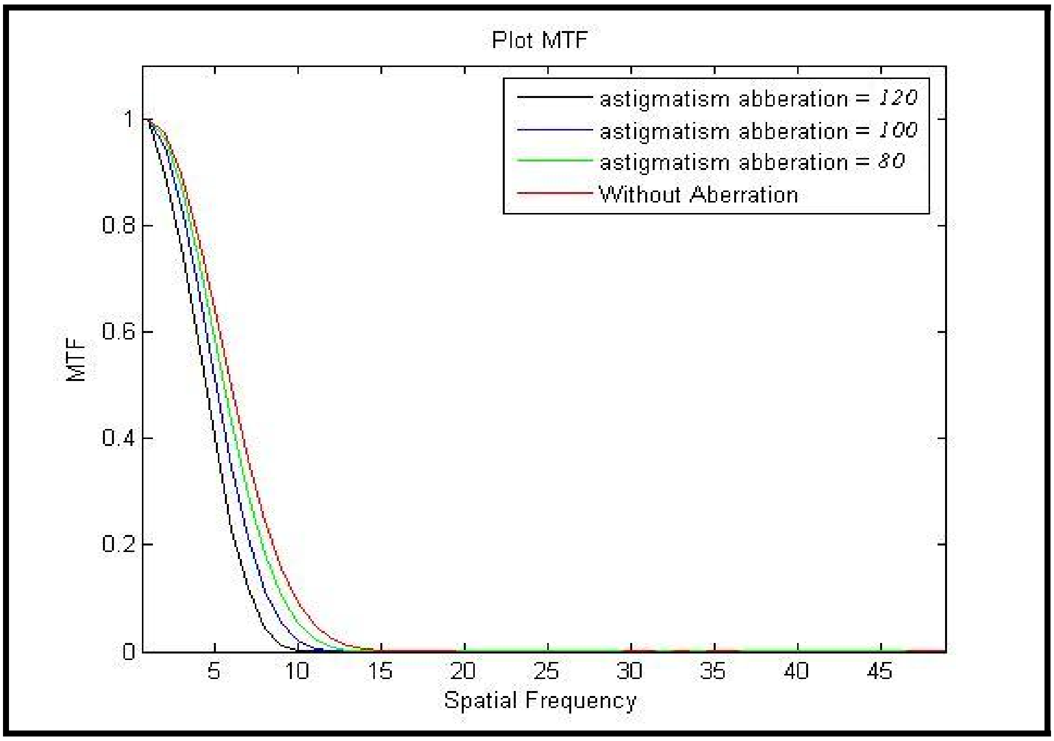


Figure (4.9) shows the MTF with Astigmatism aberration (diameter=6mm, Astigmatism =80,100,120)

From the previous results, we see that spherical, coma and astigmatism aberrations affect the MTF values for different aperture. As the aberration coefficient value increase the MTF contains only the lower frequency information, and is cut off from the MTF of aperture with no aberration.

2 Human effects 4.

In this work the Ijspeert models have been used to describe the effect of some defects on the human eyes they are:

a. Age of human.

b. The pigmentation of the human eye.

c. The pupil diameter of human eye.

1. Pupil size (diameter)

Figure (4.10) shows modulation transfer function with different pupil diameter for age of 10 years, for blue eye. Three different values of pupil diameters have been used 4mm, 5mm, and 6mm. The MTF is significantly more depressed at larger pupil size.

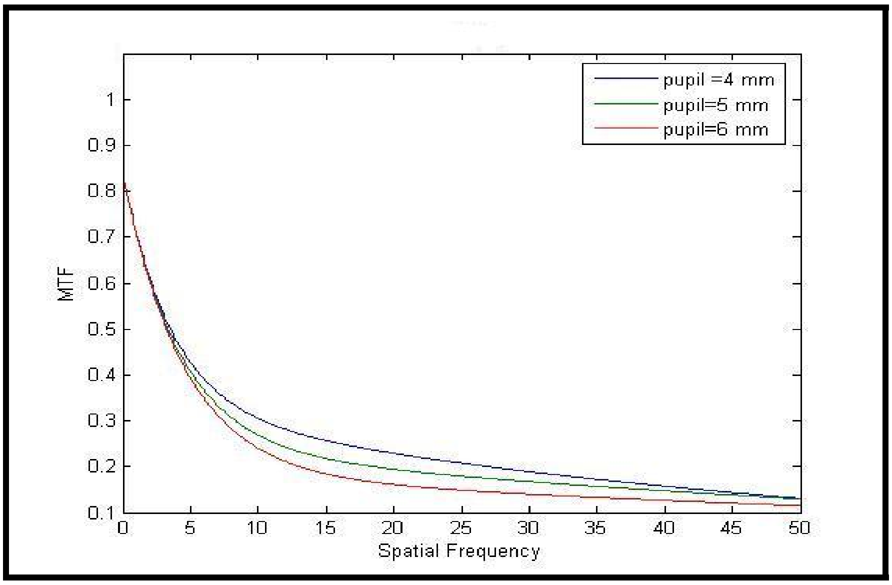


Figure (4.10) represent MTF changing with diameter of pupil blue eye for age 10 years

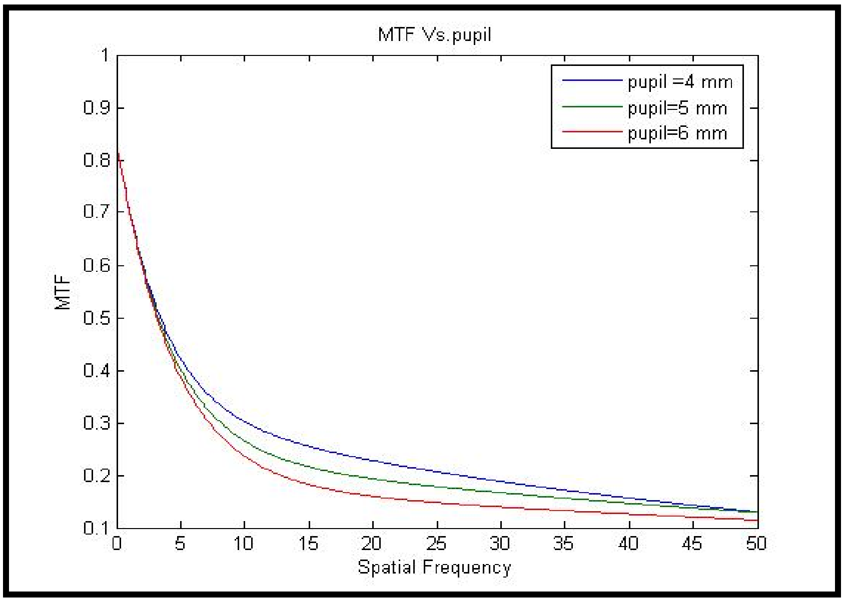


Figure (4.11) show MTF with different diameter of pupil eye for blue eye age 30years

Figure (4.11) shows MTF with different pupil eye for age 30 years for blue eye. The MTF value is more when the pupil diameter of eye increases.

Figure (4.12) shows the MTF for age 50 years for blue eye. The graphs Show that variation in MTF exists depending on the pupil diameter. The MTF decreases with age for the same pupil diameter, due to increases of large –angle scattering with age.

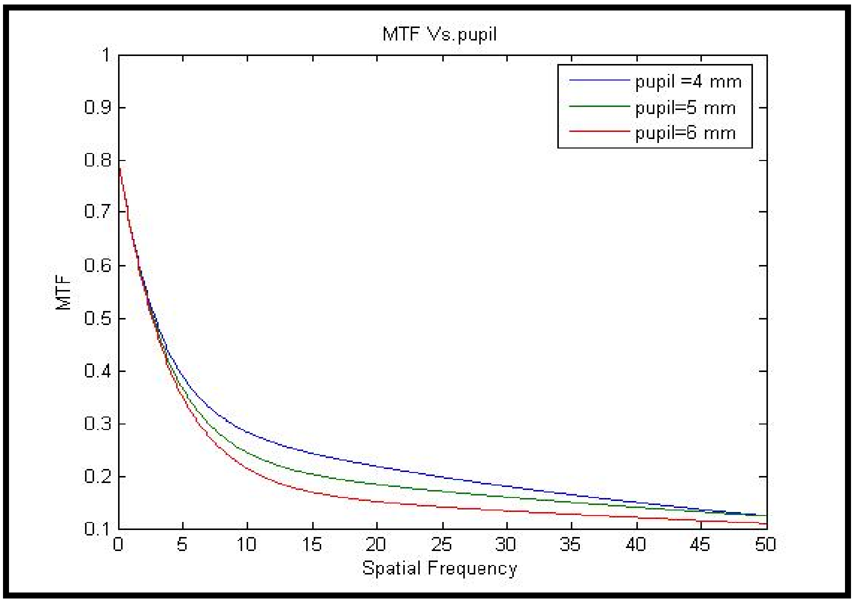


Figure (4.12) show MTF with different diameter of pupil for blue eye for age 50 years

2. Age

As a person grows older, the crystalline lens becomes harder and harder, and the muscles that control its shape grow weaker and weaker, thus making accommodation more and more difficult. Figure (4.13) shows MTF for different ages with brown eye for diameter 4mm. Figure (4.14) shows MTF for different ages with brown eye for diameter 5mm. figure (4.15) shows MTF for different ages with brown eye of diameter 6mm.

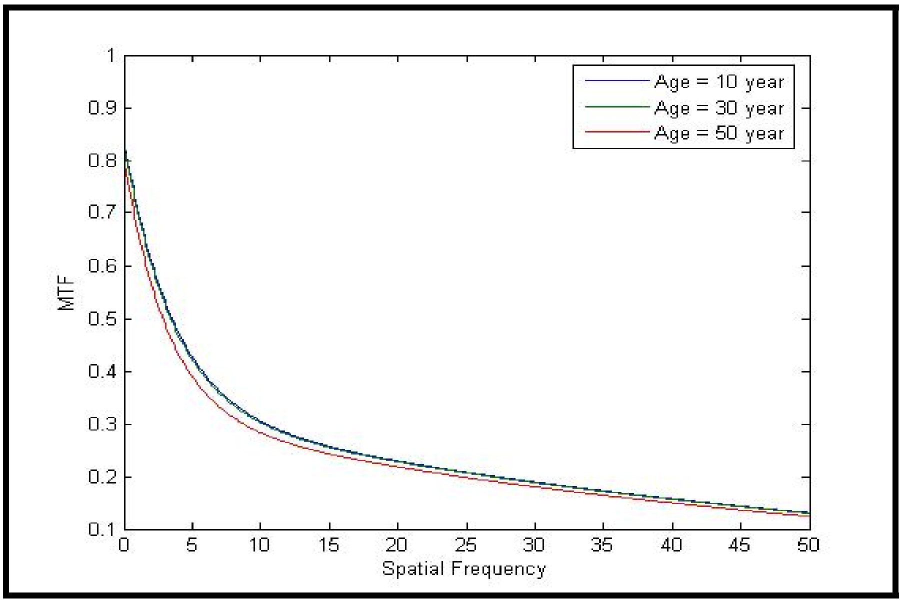
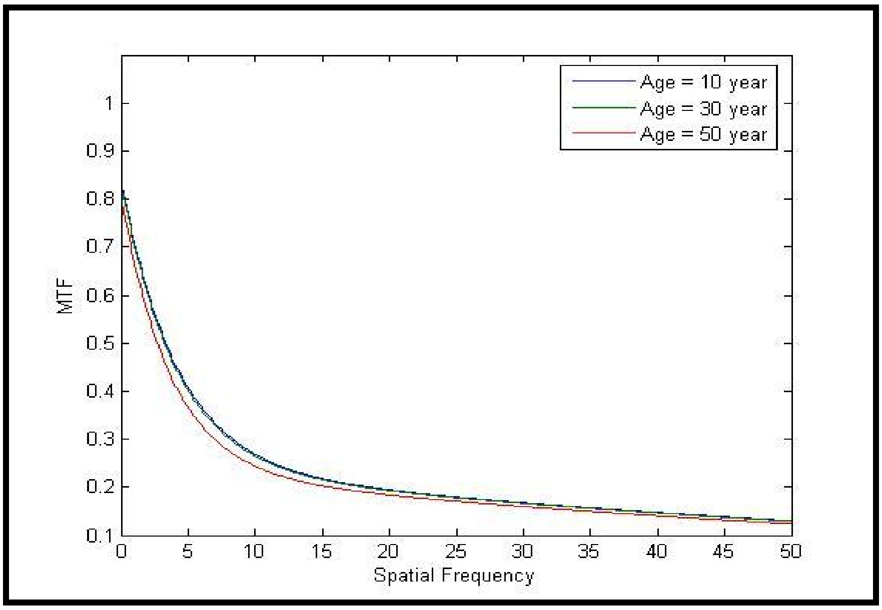


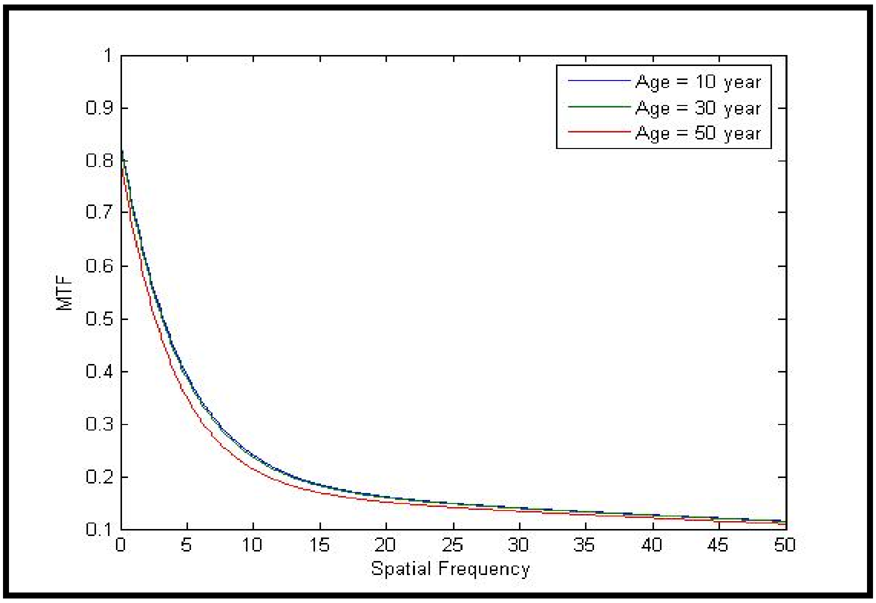
Figure (4.13) show the MTF for

brown eyes with diameter 4mm for 10, 30 and 50 years old.



The figure (4.14) show the MTF for

brown eye diameter 5mm for 10, 30 and 50 years old.



The figure (4.15) shows the MTF for brown eye diameter 6mm for 10, 30 and 50 years old.

3. Pigmentation

The pigmentation state of the eye influences both isotropic and non isotropic scattering. The parameter m is chosen depending on the color of the eye. Variation of the MTF with the final parameter pigmentation is shown below. There is a slightly higher response for darker pigments.

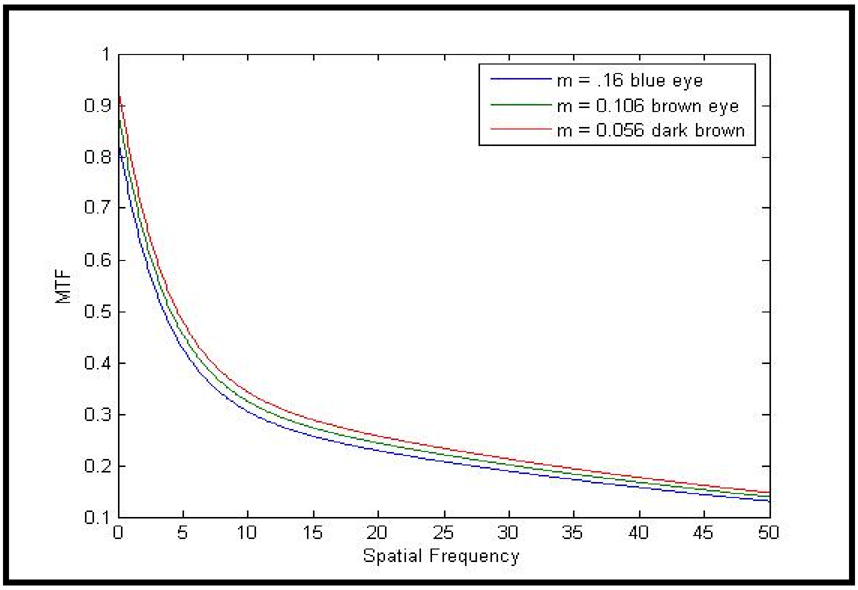


Figure (4.16) show MTF with different pigmentation factor for 10 years age and 4mm

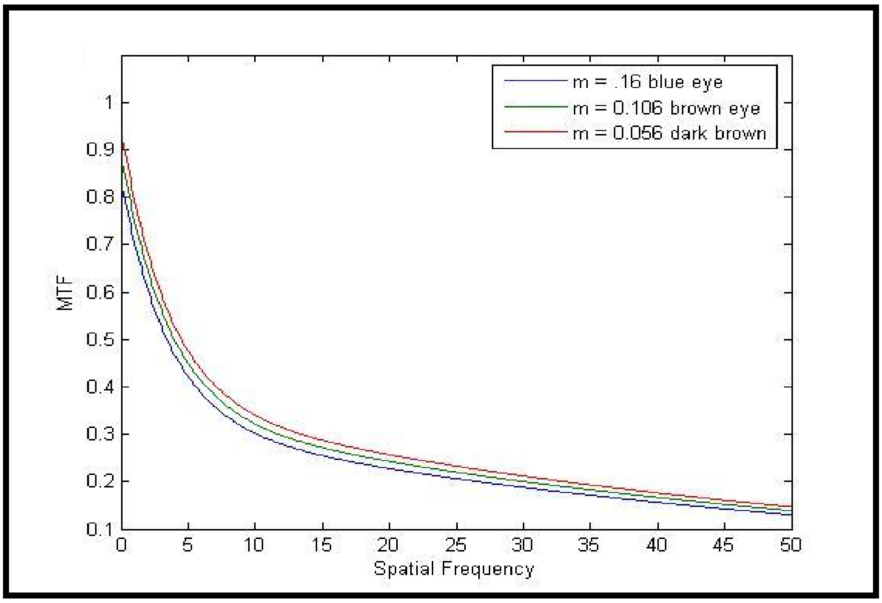


Figure (4.17) show MTF with different pigmentation factor for 30 years age and 5mm

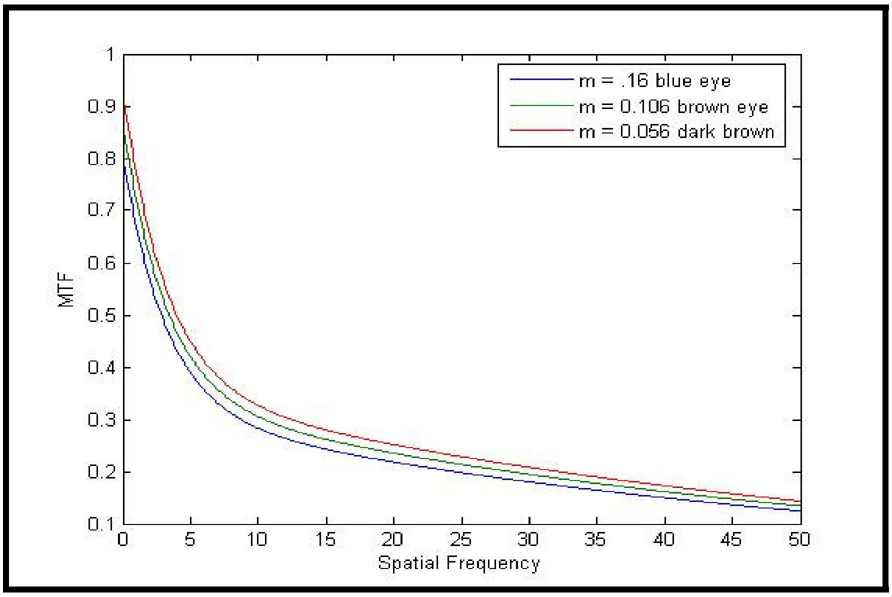
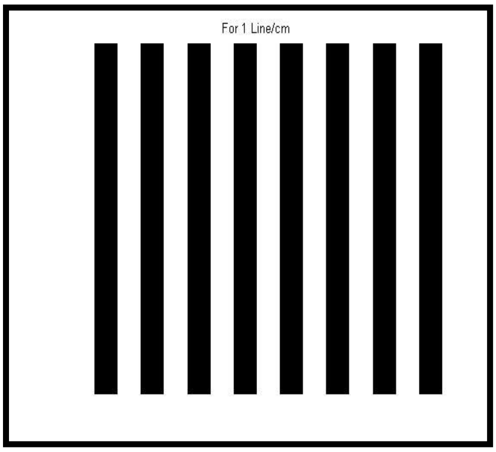


Figure (4.18) show MTF with different pigmentation factor for 50 years age and 6mm

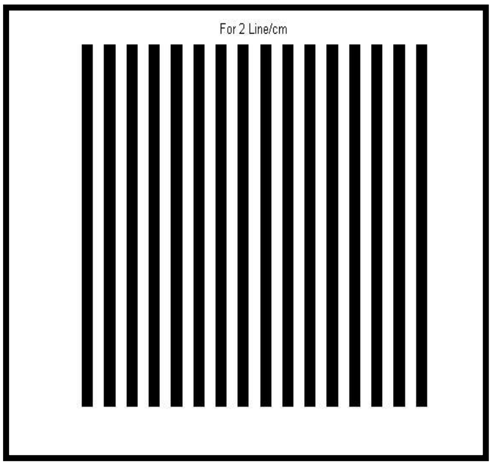
From the above results we can conclude that the MTF value decreases with the age and the blue pigmentation reduces MTF value compared with black and brown color eyes.

4.3 Experimental Setting

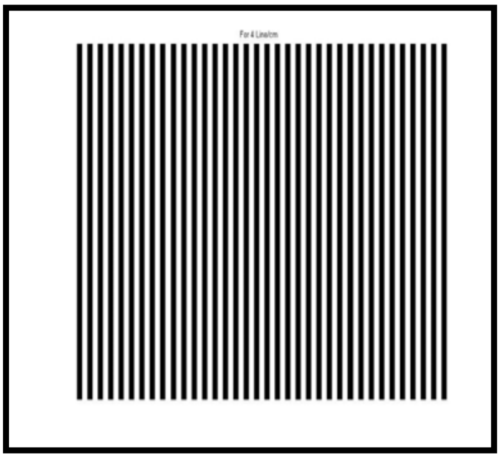
in order to study the effect of age on the quality of eye images, computer charts with different spatial frequencies (resolution) and colors (contrast). The charts are created with low and high frequencies resolution. Four charts in black, red, green, and blue color with 1, 2, 3, 4, and 5 line/cm. are shown in figures (4.19, 4.20, 4.21, and 4.22) using these charts, resolution test were done for seven peoples with date of births, 1950, 1984, 1986, 1987,1988, 1993, 1998. The measurements were conducted in good illumination condition and at distances of 4 and 6 m from the charts.



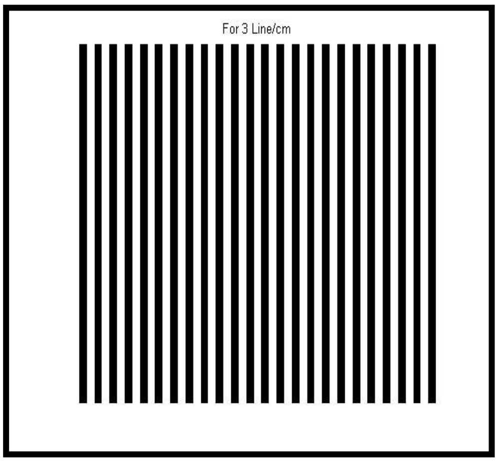
1 line/cm



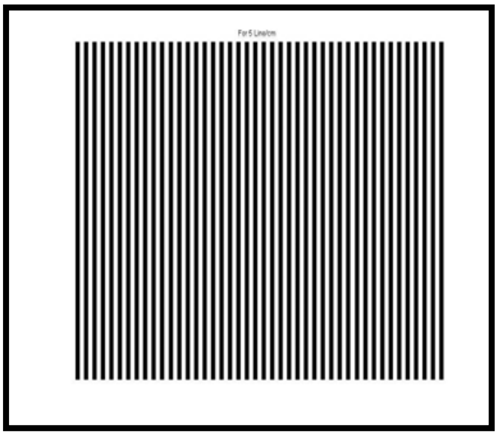
2 line/cm



4 line/cm

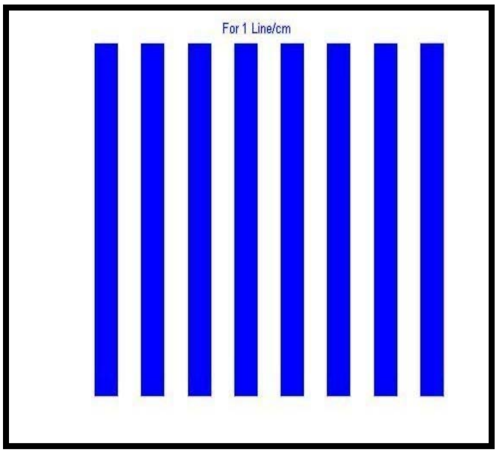


3 line/cm

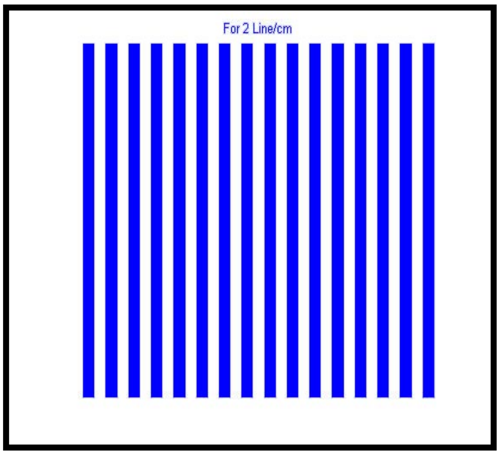


5 line/cm

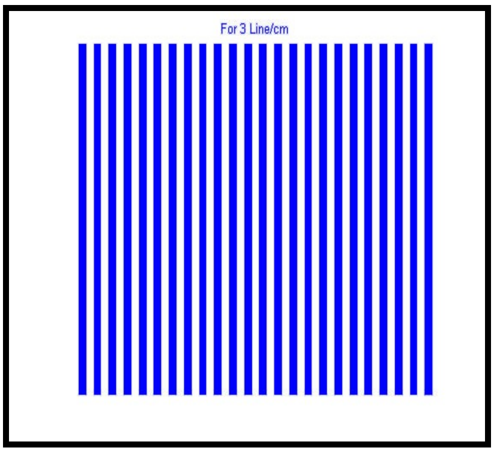
Figure (4-19) Different spatial frequencies chart for black color



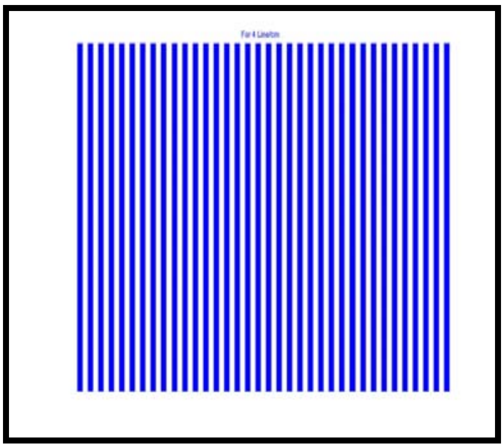
1 line/cm



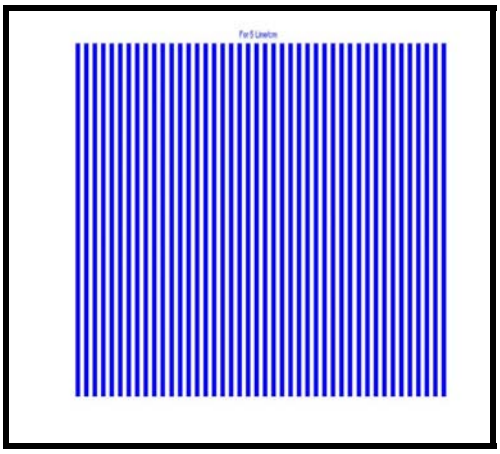
2 line/cm



3 line/cm

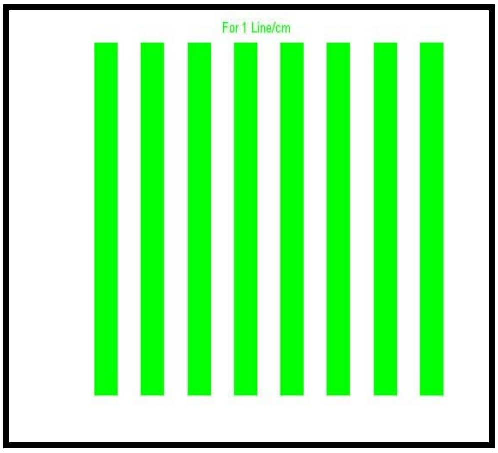


4 line/cm

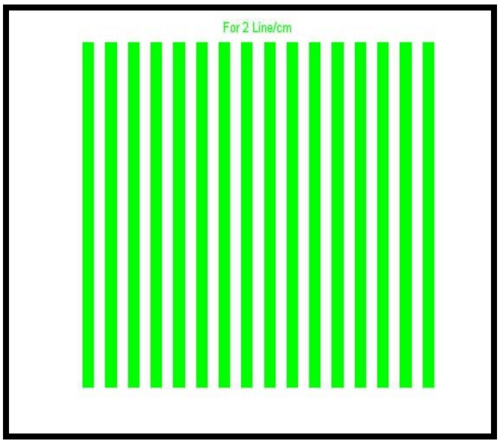


5 line/cm

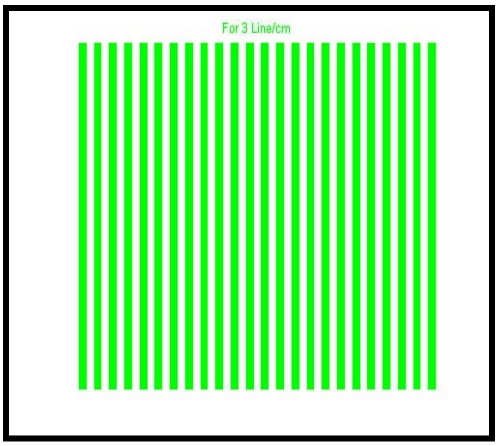
Figure (4-20) Different spatial frequencies chart for blue color.



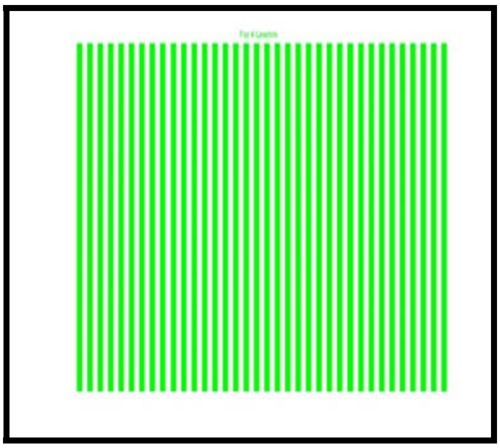
1line/cm



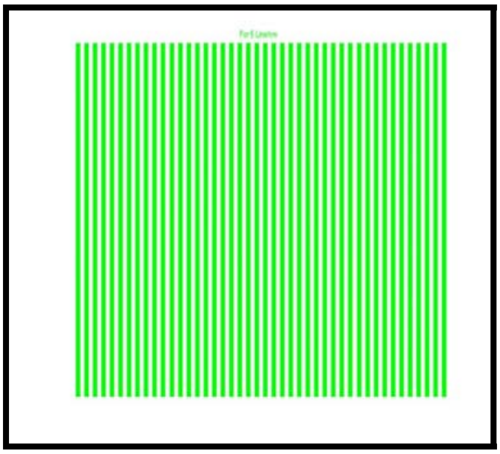
2 line/cm



3 line/cm

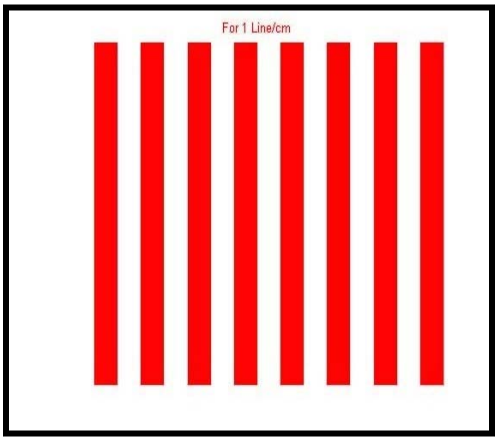


4 line/cm

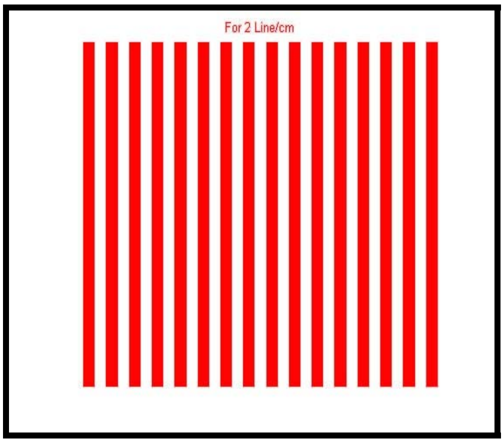


5 line/cm

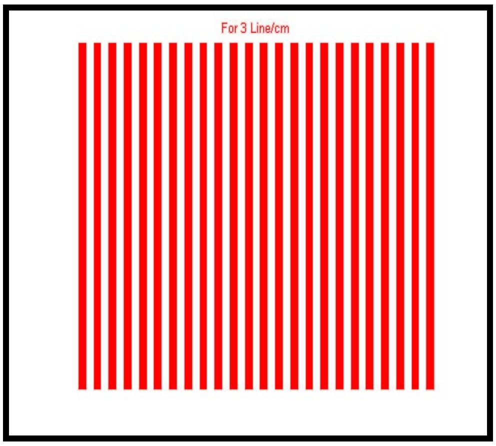
Figure (4-21) Different spatial frequencies chart for green color.



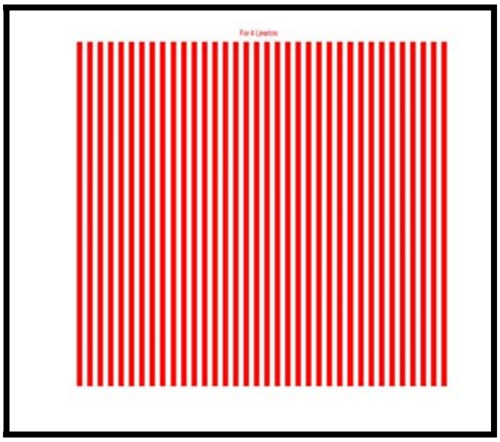
1 line/cm



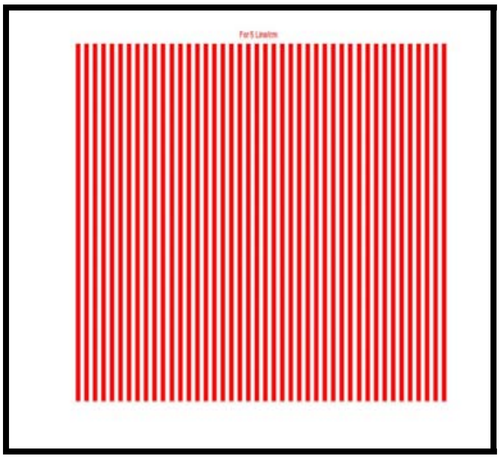
2 line/cm



3 line/cm



4 line/cm



5 line/cm

Figure (4-22) Different spatial frequencies chart for red color.

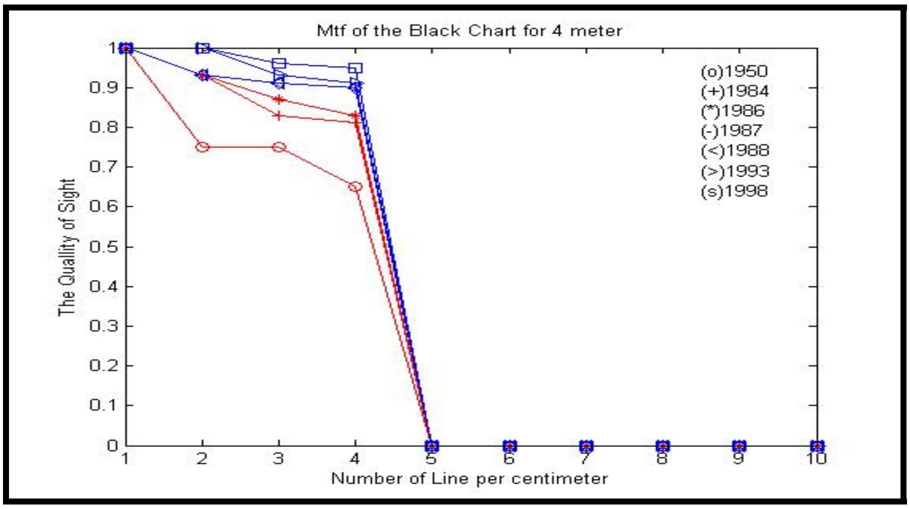


Figure (4-23) the quality of sight Vs. no. of line per centimeter.

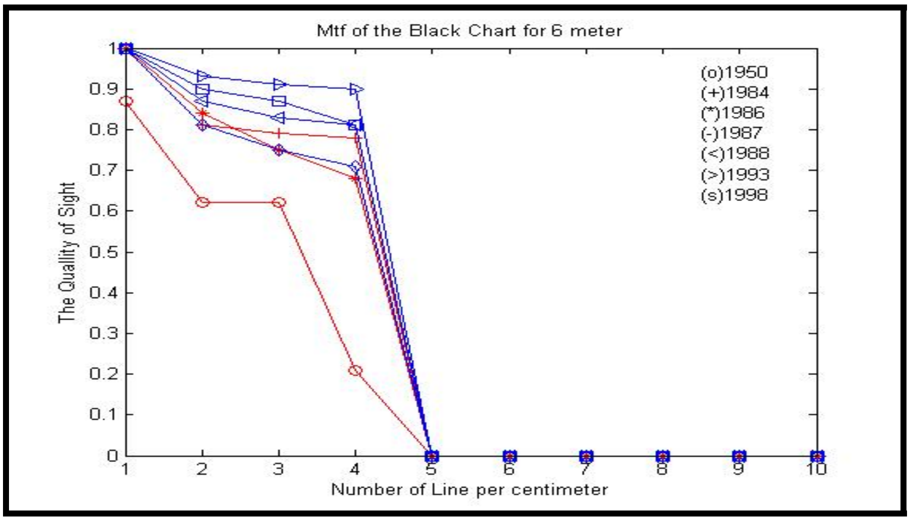


Figure (4-21) the quality of sight Vs. no. of line per centimeter.

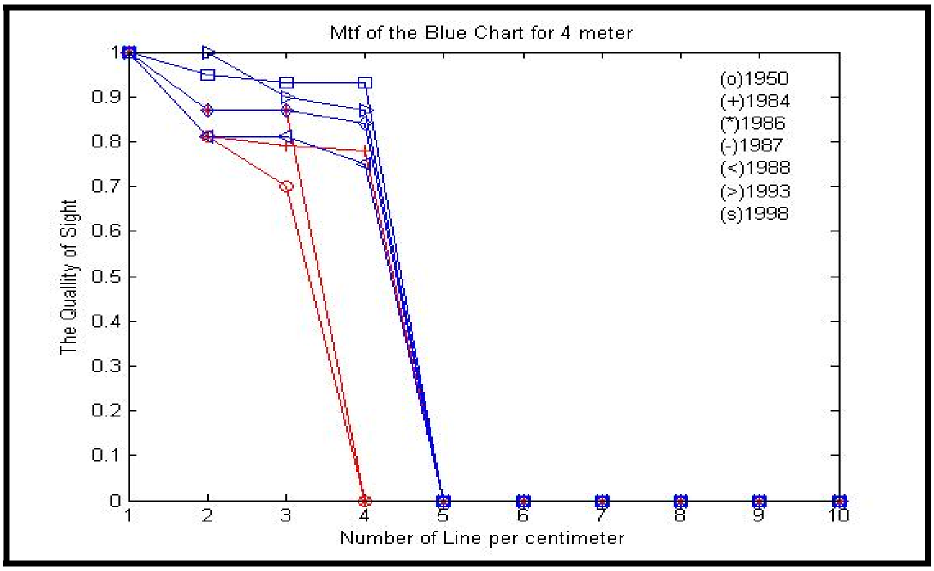


Figure (4-22) the quality of sight Vs. no. of line per centimeter.

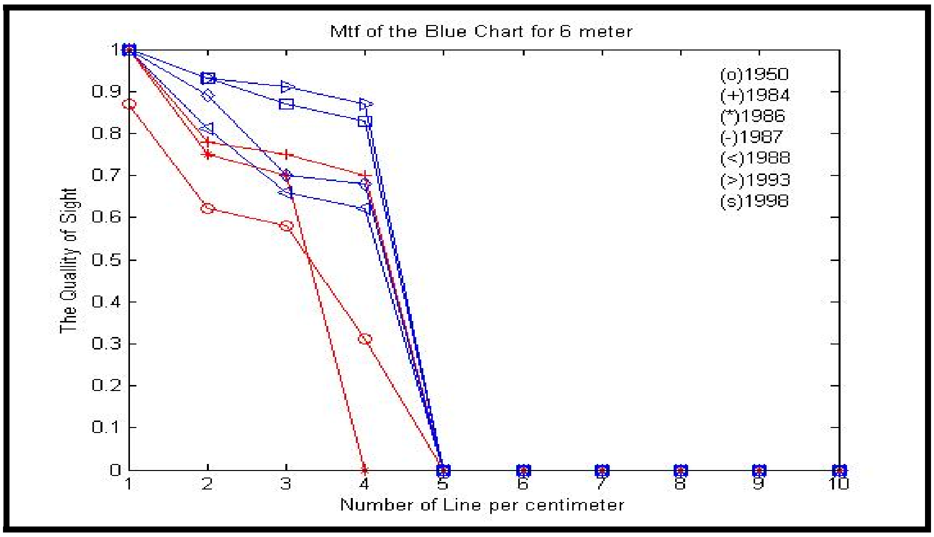


Figure (4-23) the quality of sight Vs. no. of line per centimeter.

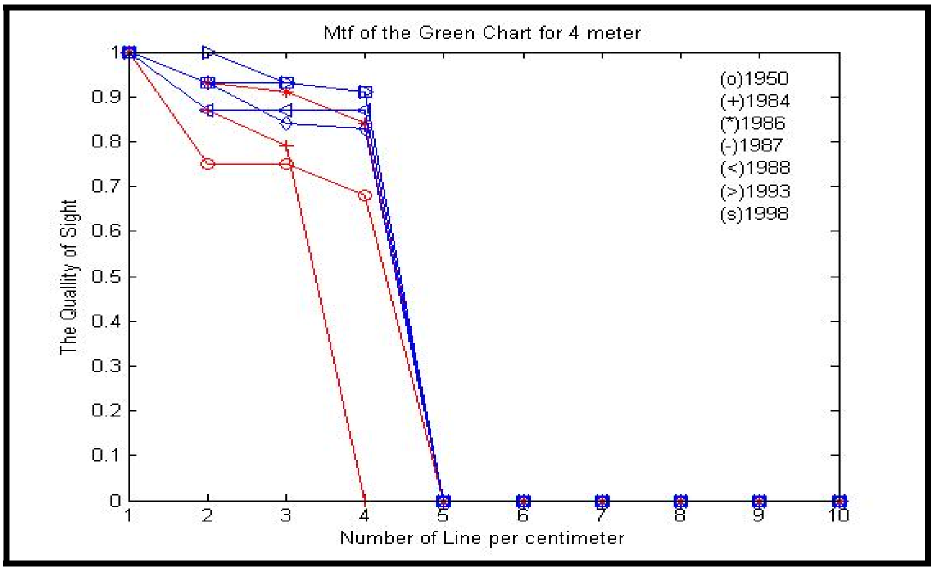


Figure (4-24) the quality of sight Vs. no. of line per centimeter.

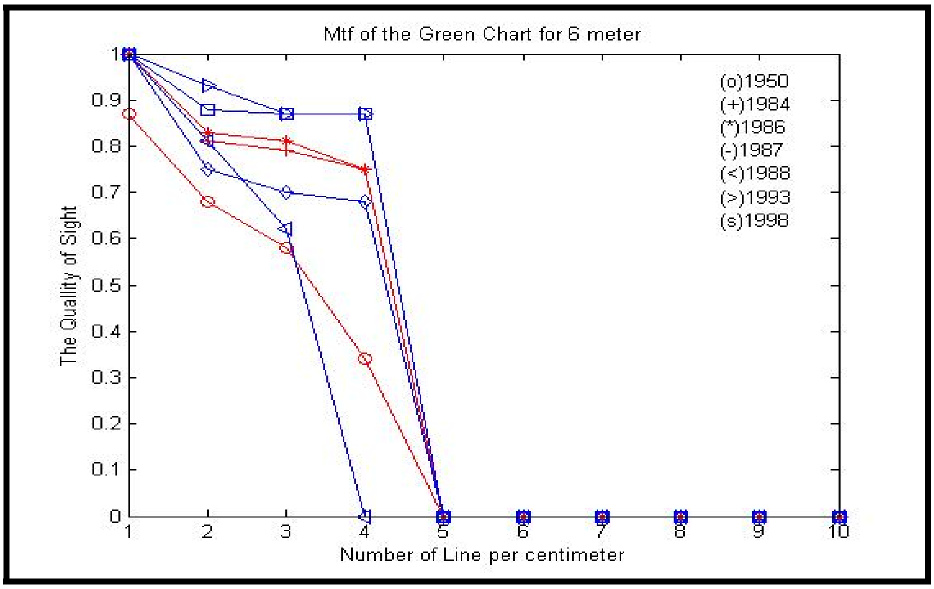


Figure (4-25) the quality of sight Vs. no. of line per centimeter.

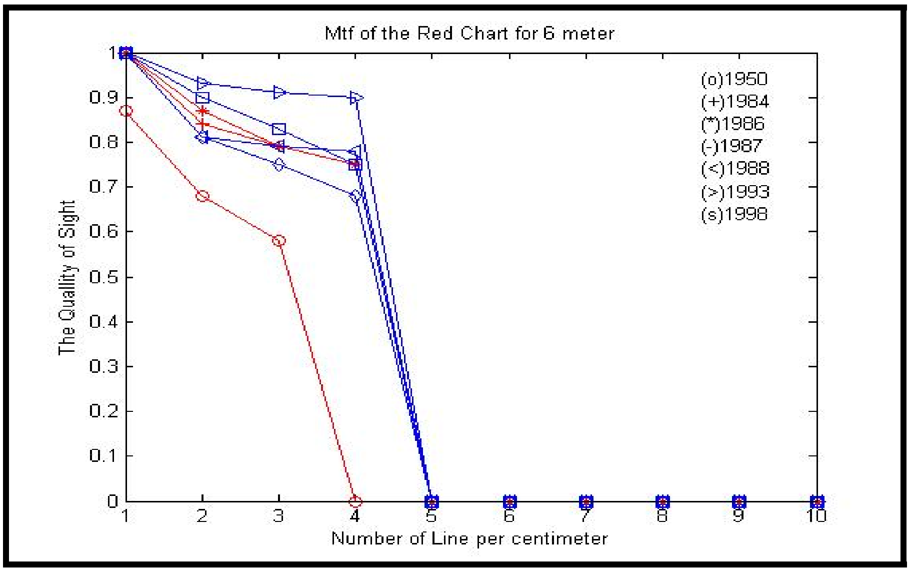


Figure (4-26) the quality of sight Vs. no. of line per centimeter.

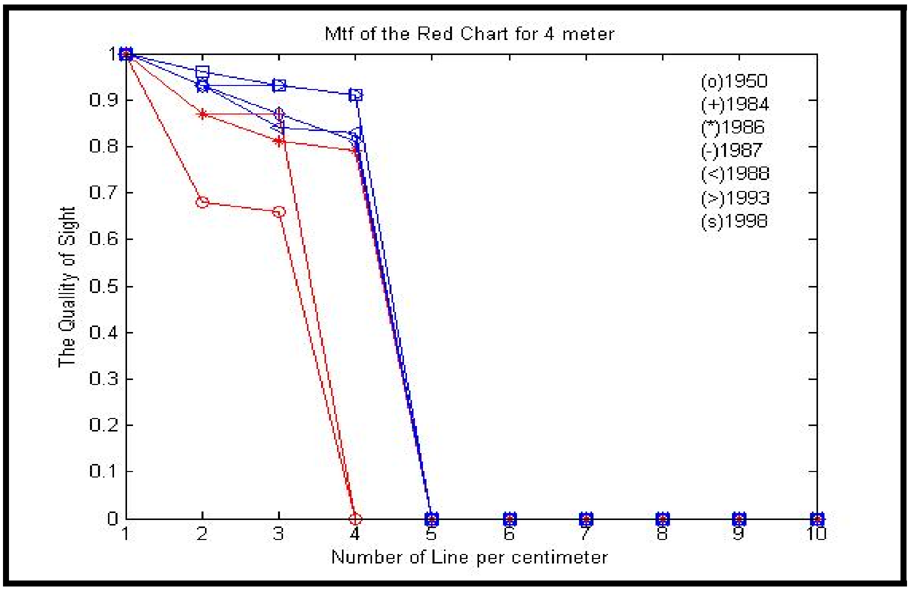


Figure (4-27) the quality of sight Vs. no. of line per centimeter.

The results obtained from the experimental part show that:

1. Increasing the distance between patients and charts decrease MTF value for all ages and all charts.
2. Black charts (with different spatial frequencies) give the highest value of MTF for all ages and all distances, this is due to the high contrast between black and white colors. While the red chart shows the lowest value.

CHAPTER FIVE

CONCLUSIONS AND FUTURE WORK

5.1 Conclusions and Future Work:-

This chapter contains the main conclusions and suggestions for research areas where future work could be useful. it is well known, that the actual resolution of any imaging system is lower than its theoretical diffraction limited resolution. Due to this fact, the effects of a pupil diameter of eye, age, pigmentation of human eye, and optical aberration on an imaging system are studied quantitatively using computer simulation models.

5.1.1 Theoretical Results

In this work MTF represent the efficiency of human eye, the age of study cases used in theoretical part were 10, 30 and 50 year. The following conclusions are extracted:

1. Age have bad effect on the image quality of human eye reducing the MTF value.
2. MTF for black eye is higher than brown and blue, for each ages used in this study this mean color pigmentation effects badly image quality.
3. Best MTF have found for 4mm eye diameter for each years under consider in this study.
4. The degree of aberrations (astigmatism, coma and spherical) were the major effect factor on MTF. The degradation on image quality increase with increasing of aberrations degree.

5.1.2 Experimental Results

In this part of work, seven people with different ages (date of births, 1950 , 1984, 1986, 1987, 1988, 1993 and 1998) were studied.

Five spatial frequency charts with 1,2,3,4 and 5 line/cm in four colors (black, red, green, blue) were used.

This part of work is conducted by placing the charts at 4 and 6 meter from the person, the measurement were done in good lighting conditions.

The main results obtained from this part of work can be summarized us follows:

1. MTF value reduces with increasing spatial frequency for all color.
2. colord chart (red,green and blue) reduce the value of MTF comparing with MTF for black color for all people.
3. MTF for older person (date of birth 1950) is less than MTF of younger people and for each color.

5.2 Future Works: -

study the other effects on the efficiency on the human eye as:-

1. Intensity of the light.
2. The difference between the male or female.

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المستخلص

دراسة العين البشرية والعوامل المؤثرة عليها من الدراسات المعقدة والصعبة بسبب عدم وجود أجهزة دقيقة لقياس كفاءة العين.

العين البشرية هي جهاز بصري عملها مشابه لعمل الكاميرا لكن العين لا تستطيع ارجاع الصورة التي التقطتها وهذا العمل تقوم به الكاميرا وتتأثر هذه المنظومة البصرية بالعديد من المتغيرات , كالزيوغ والأمراض البصرية وكذلك تتأثر العين ببعض الأمراض التي تؤثر على كفاءة العين مثل :-

1. بعد البصر

2. قصر البصر

3. أمراض أخرى

لقد درست الخصائص البصرية لمنظومة التصوير للعين البشرية والعوامل المؤثرة عليها مختبريا عن طريق موديلات حاسوبية،حيث تم في هذا البحث بناء موديلات حاسوبية لملاحظة تأثير العوامل المختلفة على جودة الصور الملتقطة بالعين البشرية شملت هذه المؤثرات على تأثير العوامل البشرية مثل العمر, صبغة العين , وبعض أنواع الزيوغ .

وقد تم دراسة تأثيراتها كميا من خلال دالة تضمين الأنتقال (MTF)، وكذلك ايجاد العلاقات الرياضية التي تربط معدل تردد مركبات دالة تضمين الأنتقال مع تأثير فتحة العدسة, الزيوغ, العمر وصبغة العين.

النتائج أظهرت ان دالة MTF مناسبة لدراسة جودة الصور و كذلك ظهر تأثير عوامل العمر وانواع الزيوغ واضح على شكل منحني MTF وكذلك ظهر هناك تماثل بين النتائج المختبرية والنظرية.

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة النهرين

كلية العلوم

دراسة لجودة الصورة للعين البشرية

رسالة

مقدمه الى كلية العلوم جامعة النهرين كجزء من متطلبات الحصول على درجة ماجستير علوم في الفيزياء

من قبل

أزهار عويد كاظم

(بكالوريوس ٢٠٠٥)

بأشراف

الدكتور صلاح عبد الحميد صالح

أيلول ***رمضان***

2008 ***1429***