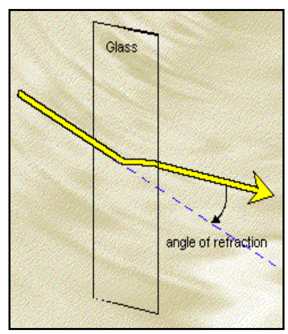
UNDERSTANDING LENSES

INTRODUCTION

This article is part of the “Understanding CCTV Series” which are abstracts from STAM InSight - The Award Winning CCTV Program on CD-ROM. This CD-ROM has many innovative CCTV tools for skill and productivity enhancement.

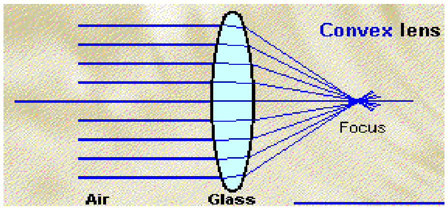
The main function of a lens is to focus the scene on to the CCD chip of a camera. This important function is often under rated, causing problems after the CCTV system is installed. A data sheet for lenses usually contains many specifications like focal length, F-stop, depth of field etc. This article will not cover these features but concentrate instead on the construction of a lens and the important factors which determine its quality. A step by step guide will also be given on how to choose a lens for an application.

CONSTRUCTION OF A LENS



To understand the construction of the lens, it is important to understand the theory of light. The speed of light when travelling through air is roughly 300,000km per second or 186,000 miles per second. When light passes from air into a denser medium at an angle, like glass or water, its speed slows down by the index of refraction of the medium. The following table gives a comparison for the various mediums.

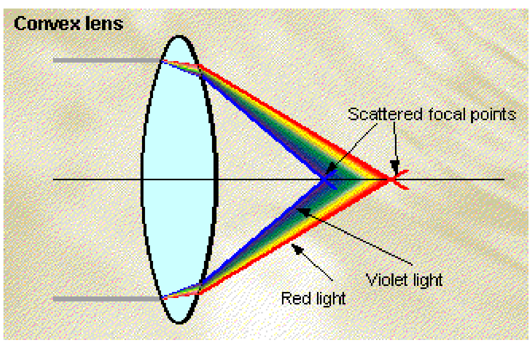
Medium	Index of Refraction	Speed of Light
Air/Vaccum	1.0	186,000 m/sec or 300,000 km/sec
Water	1.33	140,000 m/sec or 225,000 km/sec
Glass	1.5	124,000 m/sec or 200,000 km/sec
Diamond	2.42	77,000 m/sec or 124,000 km/sec



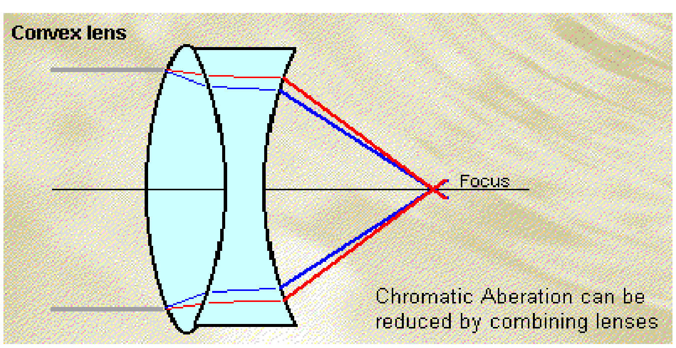
As the wave of propagation is still continuos, this slowing down bends the light beam, when it enters the new medium. It is similar to a bicycle changing direction when it enters sand from road. This basic principle is used in the construction of a lens. Convex and concave lenses are the basic lens types, which make the light beam converge and diverge respectively. These basic lens types are mixed and matched to give a wide variety of lenses.

Chromatic Aberration of Light

When light is refracted through glass a lens error called *chromatic aberration* occurs.



What is chromatic aberration? Simply it is this: Visible light is made of different colors and each color has a different frequency. These colors will bend differently compared to each other when they pass through a single convex lens, resulting in a scattered focal point (as shown in the diagram), meaning the picture will not be focused properly. To overcome this error, several different lenses are grouped together. This can make the lens construction complex and therefore more expensive. There are lenses available which do not resolve the chromatic error accurately and are not compatible for use with color cameras, as they will not give a sharp focus for all the colors in the picture. The same reasoning and logic is applicable for the infra red frequency range also. For this reason, in many cases, when an infrared illuminator is used with a monochrome camera the picture is not properly focused.



Different Glass groups in a lens

Many people are under the impression that a lens is made up of a single lens. This is not true. Besides glass pieces required for correcting chromatic aberration, additional glass is also required for:

- To focus the lens on objects at different distances

When the lens focus moves from one object to another at a different distance, or when it follows a moving object, the lens elements reposition, i.e. the focal point changes and the picture thus always remain clear. This is not a problem with the human eye, which varies the thickness of the lens. A long way to go to catch up with this advanced technology!

- To achieve different focal lengths in a zoom lens

The glass pieces move in relation to each other to achieve different magnification of the object, resulting in different focal lengths in a zoom lens.

Factors effecting lens quality

During construction, the following factors will determine the quality of the lens.

1. Number of glass pieces used

More glass pieces combined together in a lens may help in reducing chromatic error, improving focusing etc, but will increase light absorption, resulting in lesser light availability to the camera. There is a trade off between accuracy and absorption.

2. Absorption factor of the glass

Poor quality glass will absorb more light, again resulting in lower light availability to the camera. Obviously glass with lower absorption factor will cost more.

3. Coating and polishing:

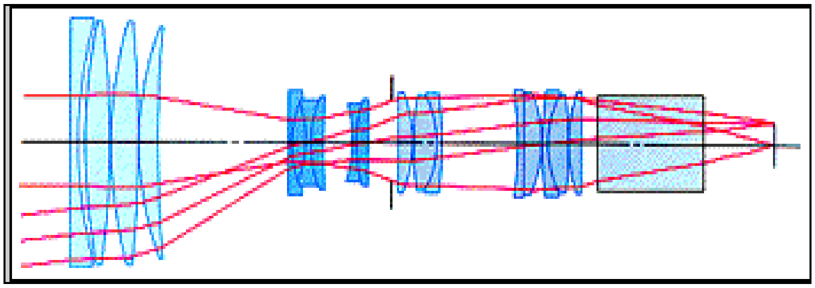
The quality of coating and polishing of the glass can improve lens quality.

4. Mechanism:

Precision and reliability of the mechanism that moves the glass pieces within the lens is important. Poor quality mechanisms can lead to inaccurate settings which may not be consistent.

Different Elements of a Zoom Lens

A zoom lens is a lens that can be changed in focal length continuously without losing focus. Magnification of a scene can be changed with a single lens, but every time the



position shifts, the lens must be refocused. If two lenses are combined, it is possible to change the magnification without disturbing the focus. A zoom lens is made of the

following groups

Focusing lens group

The focusing lens group brings an object into focus. It moves irrespective of the zoom ratio or current focal length.

2. Variator lens group

The variator lens group changes the size or magnification of the image

3. Compensator lens group

When moved in relation to the variator group, the compensator lens group corrects the shift in focus.

Lens groups 1 to 3 are the core of the zoom lens, and are called the zoom unit

4. Relay lens

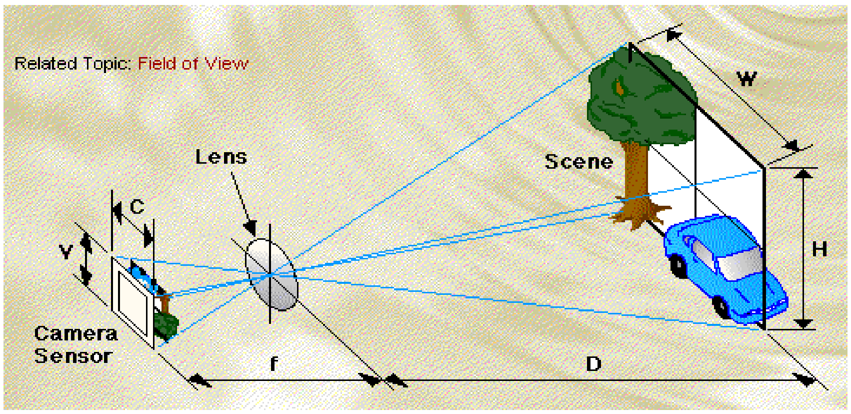
Since the zoom unit does not converge light, the relay lens group is placed behind it to focus the object on to the CCD chip.

Zoom lens design requires extensive optical path tracing and continuos self correcting performance evaluation effort. It also involves the use of powerful computers and specialist software.

CHOOSING A LENS.

Choosing the correct lens for an application is one of the most important decisions while designing a CCTV system. Experience helps but it is important to work with the end user to understand what field of view is required to be seen on the monitor. The field of view is the width and height of the scene as viewed by the lens. It depends upon the focal length and distance of the object.

Any field of view has some critical area which is the target area. For example when the camera is viewing the gate, the space the car is coming through is the critical viewing area or if one is watching the door, the space occupied by a person walking through the door is a critical a viewing area. In the same way every scene has a critical viewing area. This critical viewing area is usually ignored while selecting a lens for an application. After the installation is complete it is not uncommon to hear comments that the end user wanted to positively identify the person, but is not able to do so with the lens installed.



Step 1

Identify the scene area, which needs to be covered by the lens and estimate the width or vertical height of the scene.

Step 2

Estimate the distance from the camera to the scene.

Step 3

Calculate the focal length of the lens. The following methods can be used

1. Standard formula

The focal length can be calculated using the either the scene width or height formulas

$f = c * d / w$ or

f = v * d / h, where

c = width of the CCD chip

v = height of CCD chip

d = distance from camera

w = width of field of view

h = height of field of view

f = Focal length of lens

2. Lens wheel calculator

Many lens manufacturers provide this lens calculator. It is quite simple to use and the focal length of the lens can easily be calculated depending upon the object distance and scene dimensions. The limitation is that it does not tell how large the critical viewing area will be on the monitor.

3. Lens calculator available in the STAM InSight CD-ROM.

The STAM InSight - The Next Generation CCTV Tools on CD-ROM has an in-built lens calculator which can be used to calculate the focal length of a lens for any application. This calculator also calculates the % size of the critical viewing area in the monitor.

Step 4

As mentioned, in any scene there are areas or moving objects which are critical. It is important to understand what is required, a detection or positive identification.

Detection view - The critical viewing area should cover 5% of the monitor

Action view - The critical viewing area should cover about 10% of the monitor

Identification view - The critical viewing area should cover about 25% of the monitor.

Estimate the horizontal and vertical dimensions of the critical viewing area

Step 5

Calculate the viewing area of the scene and also of the critical viewing area by multiplying the horizontal and vertical dimensions. Divide the critical viewing area with the total viewing area to get the size of the critical viewing area in the monitor.

Step 6

1. If the proportion of the critical viewing area is as expected, use the calculated focal length.
2. If not, then change the
- focal length till the correct proportion is found or
- change the distance of the camera until the correct proportion is found
3.If you still do not find what you want, you may have to choose a lens which is the nearest to your requirement.

Example

A 1/3 inch camera is viewing an entrance gate to a factory. The car coming through the gate is the critical view.

1/3 chip; width (c) = 4.8mm   height (v) = 3.6mm

distance to gate (d) = 100 ft

width of gate (w) = 12 ft

car dimension (front) =   5 ft X 5 ft

Focal length f = c * d / w = 4.8 * 100/ 12 = 40mm

scene height h = v * d / f = 3.6 * 100 /40 = 9 ft

Scene area = 12 ft X 9 ft = 108 sq. ft

Critical area = 5 ft X 5 ft = 25 sq. ft

% size of car in monitor = 25 * 100 / 108 = 23.1%

The car will cover about 23% of the monitor. This will allow the positive identification of the car coming through the gate.

About the Author

Jayant Kapatker is an international authority on CCTV and is the brain behind STAM InSight - The Award Winning CCTV Program on CD-ROM. This interactive multimedia CD-ROM contains over 14 hours of CCTV content. This series of articles have been based upon the subjects covered in STAM InSight. For more info on the CD ROM contact INSTROM Tel: 01908 261900, Fax: 01908 261933
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