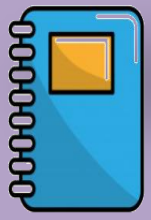
江西理工大学 Jiangxi University of Science and Technology
信息工程学院 School of information engineering


Digital Image Processing
数字图像处理

Lecture 04:
Digital image fundamentals

Dr Ata Jahangir Moshayedi

Prof Associate ,
School of information engineering Jiangxi university of science and technology, China



EMAIL: ajm@jxust.edu.cn

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江西理工大學 信息工程学院

JIANGXI UNIVERSITY OF SCIENCE AND TECHNOLOGY SCHOOL OF INFORMATION ENGINEERING

Digital Image Processing

LECTURE 04: Digital image fundamentals _A

Agenda

- Elements of visual perception
- Human eye construction
- Light And The Electromagnetic Spectrum
- A Simple Image Formation Model

Eyes and camera

眼睛和相机 Yǎnjīng hé xiàngjī

- The human eye is a wonderful instrument, relying on refraction and lenses to form images. There are many similarities between the human eye and a camera, including:

隔膜控制 Gémó kòngzhì

- a **diaphragm to control** the amount of light that gets through to the lens. This is the shutter in a camera, and the pupil, at the center of the iris, in the human eye.

镜头对焦 Jìngtóu duìjiāo

- a **lens to focus** the light and create an image. The image is real and inverted.

感知图像的方法 Gǎnzhī túxiàng de fāngfǎ

- a method of sensing the image. In a camera, film is used to record the image; in the eye, the image is focused on the retina, and a system of rods and cones is the front end of an image-processing system that converts the image to electrical impulses and sends the information along the optic nerve to the brain.

Eyes and camera similarity

眼睛和相机相似度 Yǎnjīng hé xiàngjī xiāngsì dù

Human Eyes

人眼 Rén yǎn

虹膜 Hóngmó

•Your **iris** controls how much light enters your eye 镜片 Jìngpiàn

•Your lens helps focus the light. The retina is a light-sensitive surface at the back of your eye.

•It captures an image of what you're looking at. Then, the retina sends impulses to your brain along the optic nerve. 视神经。 Shìshénjīng.

•Finally, the brain interprets what you're seeing.

Camera

相机 Xiàngjī

- This is similar to what happens when a camera captures an image. First, light hits the surface of the camera's lens.

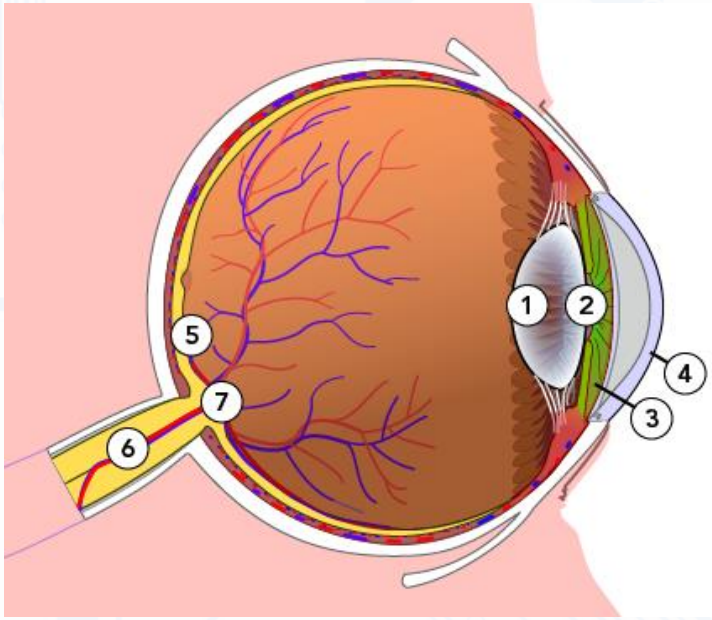
光圈 Guāngquān

- The **aperture** controls how much light enters the camera. Then, the light makes its way to a light-sensitive surface.
- For a long time, this surface was the **camera's film**. 照相机胶卷 Zhao xiàng jī jiāo juàn
- In today's digital cameras, this surface is an **imaging sensor chip**.

成像传感器芯片 Chéngxiàng chuángǎnqì xīnpiàn

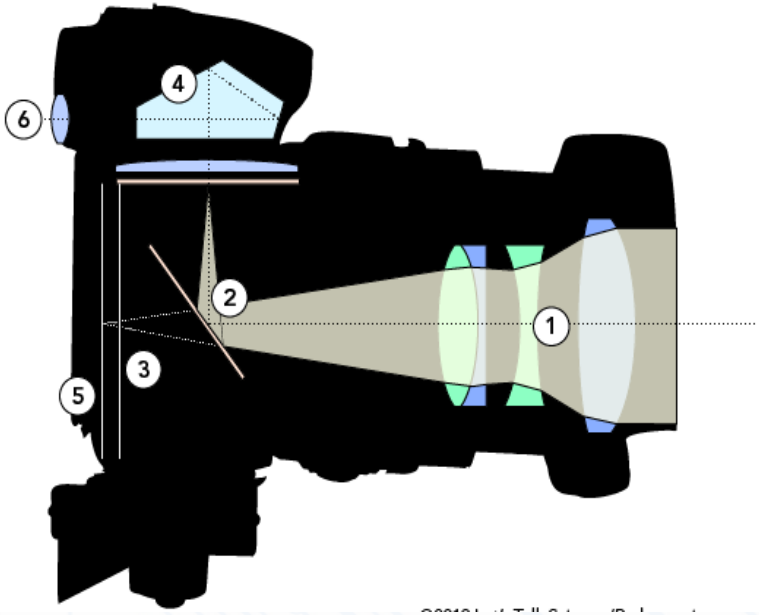
Eyes and camera similarity

Eyes 人眼 Rén yǎn



A human eye has a
lens (1), pupil (2),
iris (3), cornea (4),
retina (5), optic nerve (6), and blind spot (7).

camera 相机 Xiàngjī



An SLR camera has a
lens (1), mirror (2),
aperture (4), prism (4),
film or imaging sensor (5)
and eyepiece (6).

How are an eye and a camera different?

There are two major differences between the human eye and a camera.

- The first relates to how they focus an image.
- The second relates to how they process colour.

第一个与他们如何聚焦图像有关。
第二个与他们如何处理颜色有关。
Dì yī gè yǔ tāmen rúhé jùjiāo túxiàng yǒuguān.
Dì èr gè yǔ tāmen rúhé chǔlǐ yánsè yǒuguān.

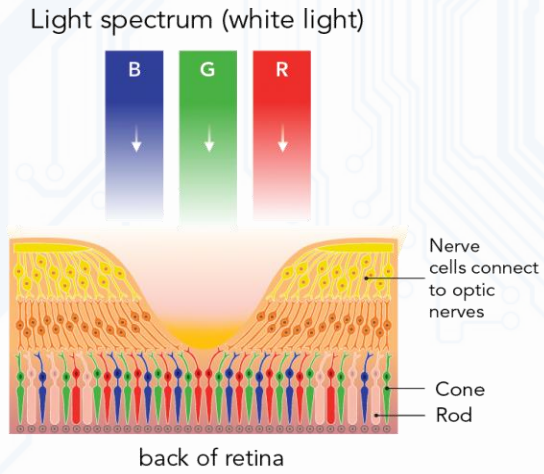
How does an eye focus differently than a camera?

- The lenses in your eyes change shape to stay focused on a moving object. The thickness of the lens also changes to **accommodate** the image being viewed. It is able to do this because the lens is attached to small muscles that contract and relax. 容纳 Róngnà
- A camera lens can't do this. That's why photographers change lenses, depending on how far away they are from an object. Mechanical parts in the camera lens also adjust to stay focused on a moving object.

How are an eye and a camera different?

There are two major differences between the human eye and a camera.

- The first relates to how they focus an image.
- The second relates to how they process colour.



How does an eye process colour differently from a camera?

光感受器 Guāng gǎnshòuqì

- Your retinas contain two types of **photoreceptors**: rods and cones. Rods allow you to see in low light. They aren't useful for colour vision.

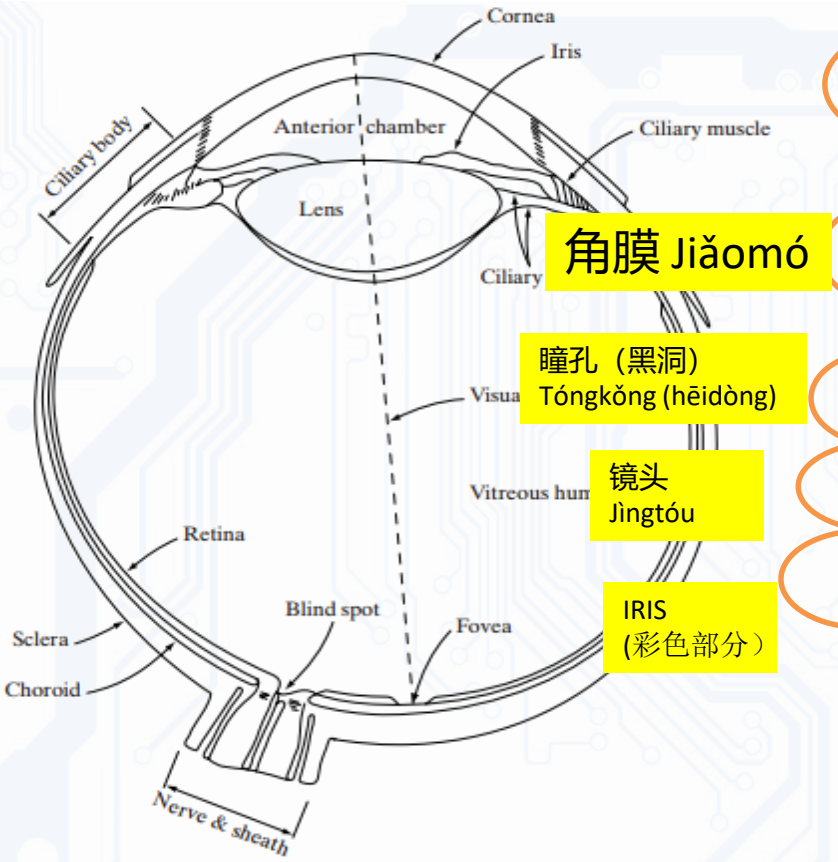
  Cones let you see in **colour**.

- There are three types of cones. Each type responds to different **wavelengths** of light. 波长 Bōcháng
  - Red cones respond to long wavelengths.
  - Blue cones respond to short wavelengths.
  - Green cones respond to medium wavelengths.

Elements of visual perception

视觉感知要素 Shìjué gǎnzhī yàosù

We will look at the following parts

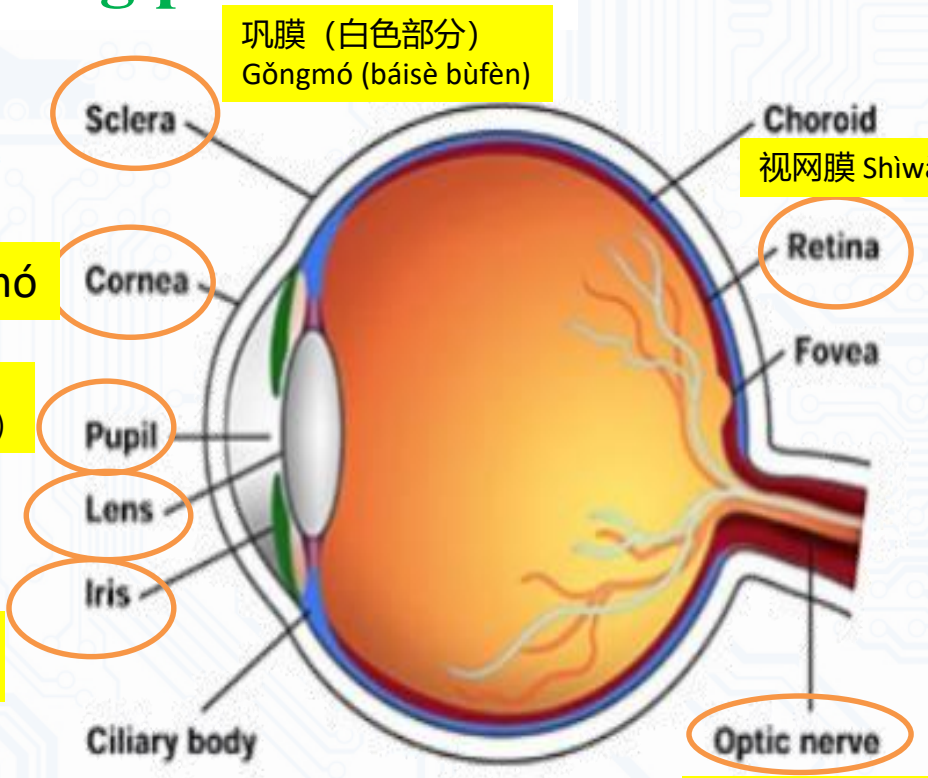


角膜 Jiǎomó

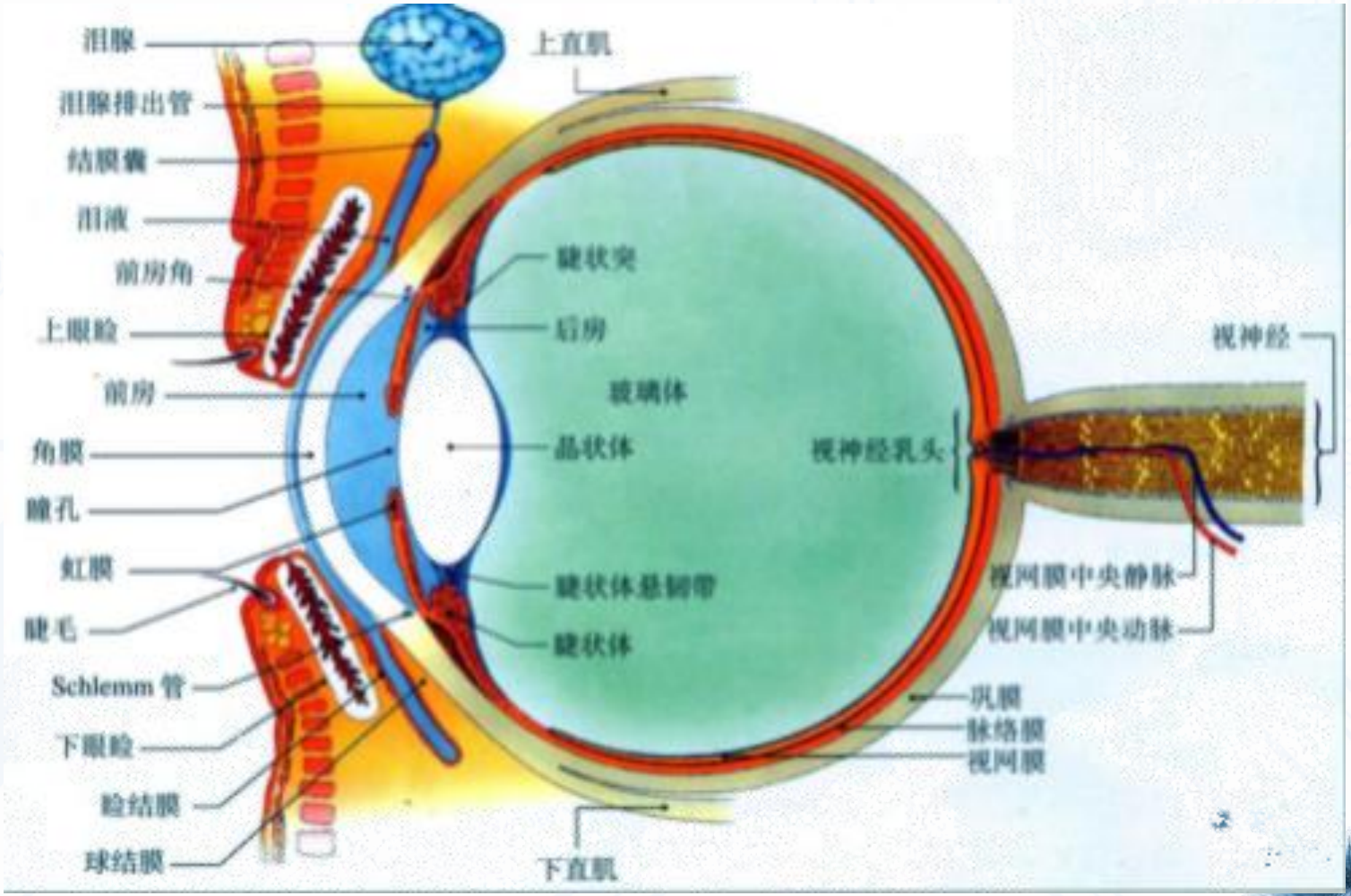
瞳孔（黑洞）
Tóngkǒng (hēidòng)

镜头
Jìngtóu

IRIS
(彩色部分）

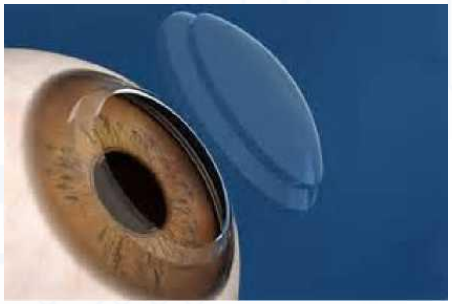


Elements of visual perception

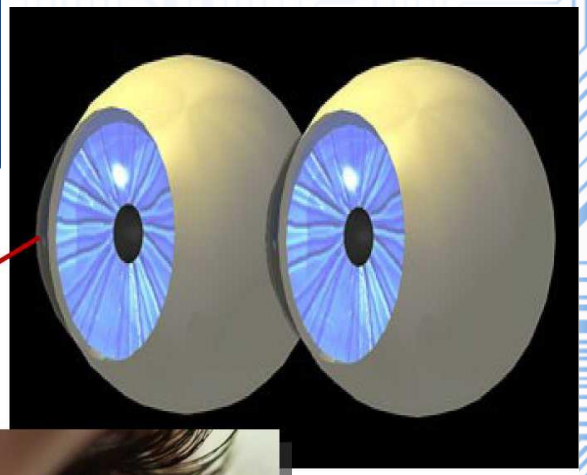


Cornea

角膜 Jiǎomó



角膜（眼前的透明镜片）
Jiǎomó (yǎnqián de tòumíng jìngpiàn)



CORNEA *(clear lens in front of eye)*

- transparent covering of the front of the eye
- Allows for the passage of light into the eye and functions as a fixed lens.

FUNCTION of Cornea

- allows for the passage of light into the eye and it also focuses the light

允许光线进入眼睛并聚焦光线
Yǔnxǔ guāngxiàn jìnrù yǎnjīng bìng jùjiāo guāngxiàn

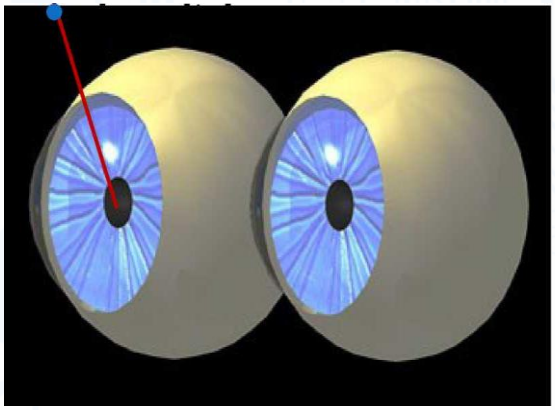
PUPIL (black hole)

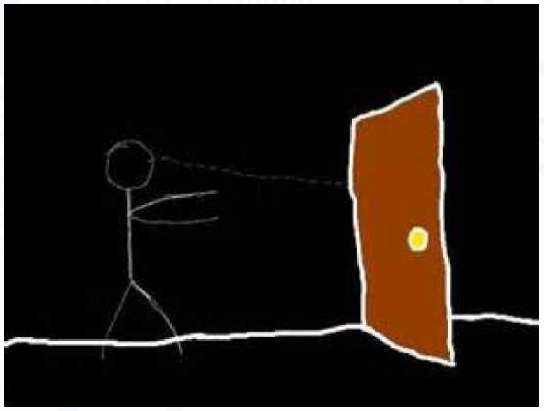
瞳孔（黑洞） Tóngkǒng (hēidòng)

- black hole in iris
  - When the eye needs **more light** to enter (when it is dark), **the pupils get larger**; allowing more light to enter the eye
  - When the eye needs **less light** to enter (when it is very bright), **the pupils get smaller**; allowing less light to enter the eye
- Pupil size is controlled by iris muscles

瞳孔大小由虹膜肌肉控制
Tóngkǒng dàxiǎo yóu hóngmó jīròu kòngzhì

- **Function of Pupil: the hole where light enters into the eye**





IRIS(colored part)

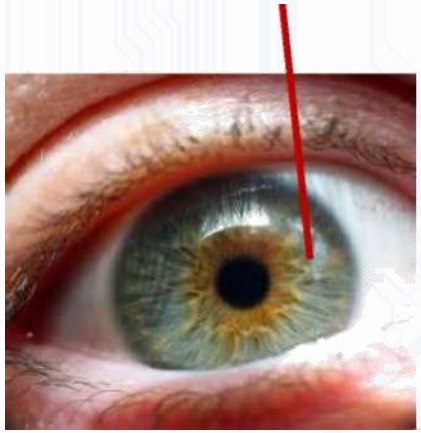
IRIS（彩色部分）

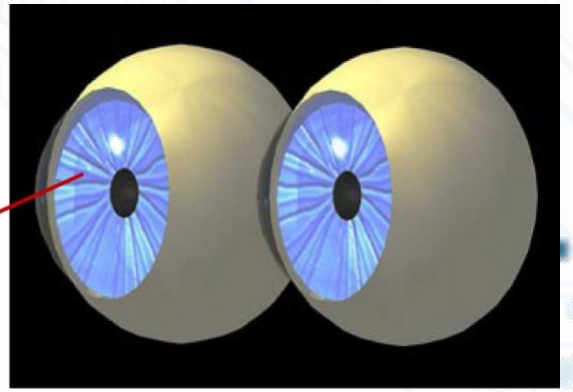
- The iris is a colored, circular muscle
- controls light entering

Function :

controls the amount of light entering the eye

控制进入眼睛的光量
Kòngzhì jìnrù yǎnjīng de guāngliàng



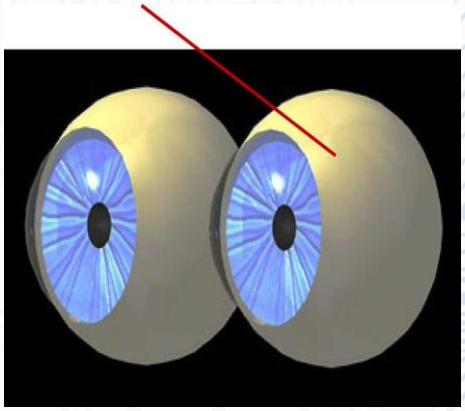


SCLERA *(white part)*

巩膜（白色部分） Gǒngmó (báisè bùfèn)

SCLERA - a tough white skin (made of tissue) that covers all of the eyeball except the cornea.

- whites of the eye
- supports eyeball
- provides attachment for



Function:

supports eyeball and provides attachment for muscles

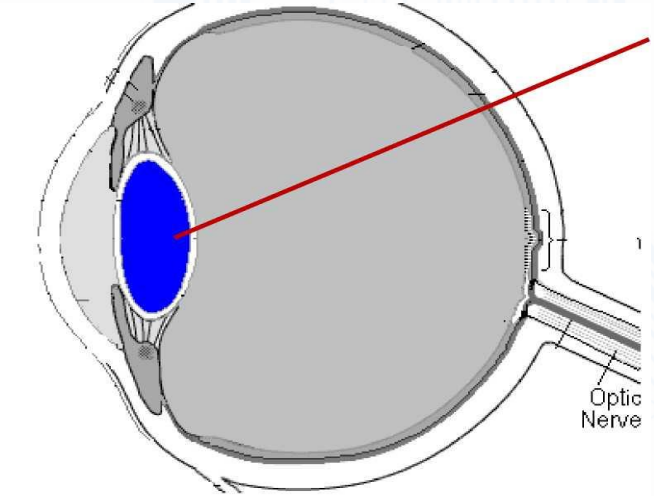
支撑眼球并为肌肉提供附着

Zhīchēng yǎnqiú bìng wèi jīròu tígōng fùzhuó

Lens *(lens behind pupil)*

镜头（瞳孔后面的镜头） Jìngtóu (tóngkǒng hòumiàn de jìngtóu)

- Converging lens
- Function:
  allows us to see objects near and far



让我们可以看到近处和远处的物体
Ràng wǒmen kěyǐ kàn dào jìn chù hé yuǎn chǔ de wùtǐ

Retina

视网膜 Shìwǎngmó

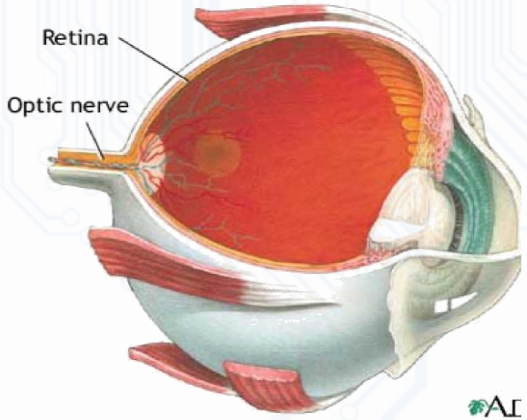
- internal membrane
- contains light-receptive cells (rods and cones)
- converts light to electrical signals

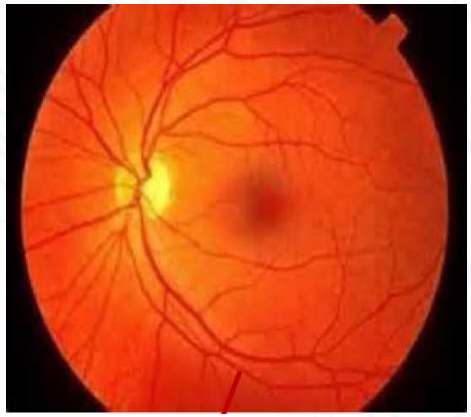
Function :

converts light waves to electrical signals

将光波转换为电信号

Jiāng guāngbō zhuǎnhuàn wèi diàn xìnhào





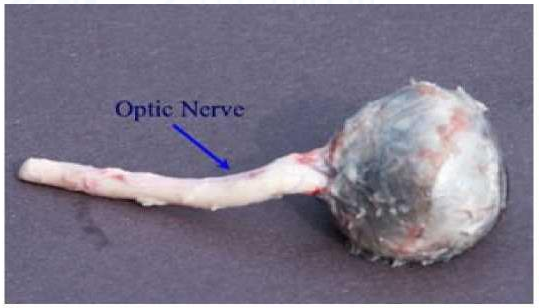
Optic Nerve

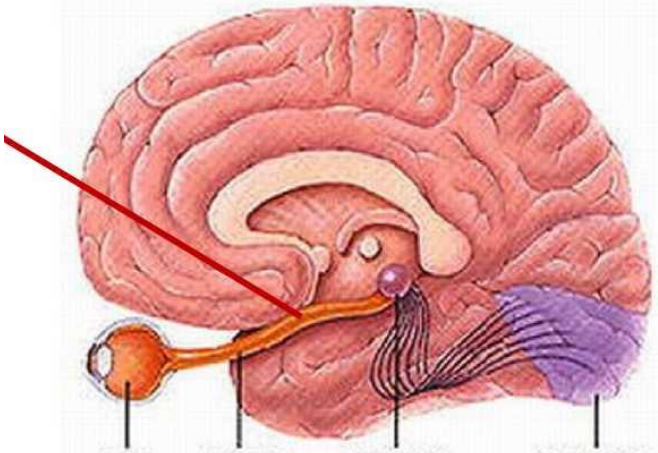
视神经 Shìshénjīng

- Transmits electrical impulses from retina to the brain Creates blind spot
- Brain takes inverted image and flips it so we can see

Function :

Transmits electrical signals from retina to the brain





将电信号从视网膜传输到大脑
Jiāng diàn xìnhào cóng shìwǎngmó chuánshū dào dànǎo

Blind Spot

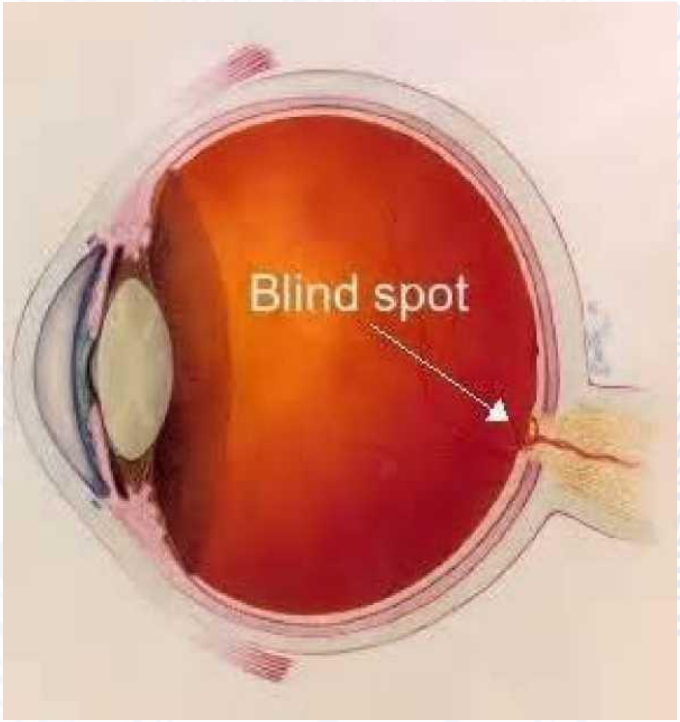
盲点 Mángdiǎn

- On retina where optic nerve leads back into the brain
- No rod or cone cells
- Other eye compensates for this area

Function:

Small spot on the back of the retina

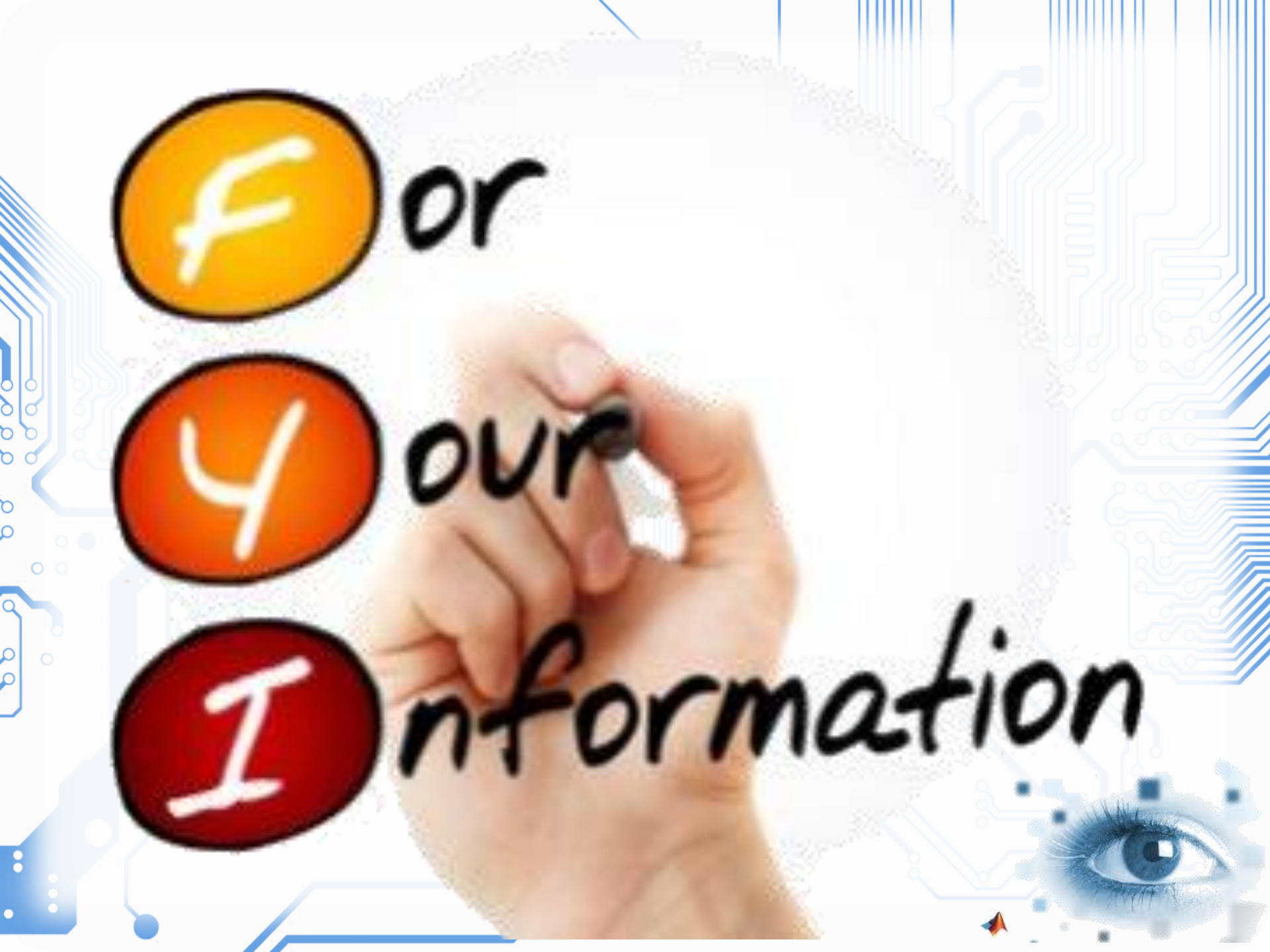
Other eye compensates for this area



视网膜背面的小点 另一只眼睛补偿这个区域

Shìwǎngmó bèimiàn de xiǎo diǎn lìng yī zhī yǎnjīng bǔcháng zhège qūyù

Let us watch from one clip


For
Your
Information

Elements of visual perception

视觉感知要素 Shìjué gǎnzhī yàosù

FYI

A human eye, nearly a sphere with an average diameter of approximately 20 mm, is enclosed by three membranes: **cornea** and **sclera, choroid** and **retina**.

角膜和巩膜、脉络膜和视网膜
Jiǎomó hé gǒngmó, màiluòmó hé shìwǎngmó

1. The **Cornea** is a tough & transparent tissue, covering the anterior surface of the eye.
2. The **Sclera** is an opaque membrane, enclosing the remainder of the eye globe.
3. The **Choroid** contains blood vessels to supply nutrients to the eye.
4. It is heavily pigmented stopping external light and is divided into ciliary body and iris.
5. Center opening of iris, known as pupil, is about 2-8 mm in diameter.
6. The front of iris is filled with visible pigments and its back with black pigments.

Elements of visual perception

视觉感知要素 Shìjué gǎnzhī yàosù

FYI

6. The lens, layers of fiberous cells, is having 60% to 70% H2O, 6% fat and rest protein. It is lightly yellowishly pigmented.

7. The retina is rich with cones and rods which are light receptors.

8. The cones, 6 to 7 millions in count are primarily located in the center of retina, known as fovea. They are responsible for photopic (bright light) vision-colour vision.

9. The rods, 75 to 150 millions in count, are distributed all over the retina. They are responsible for scotopic (dim light) vision-contrast.

10. An individual cone is connected to an individual optical nerve and hence accounts for perception of finer details.

11. Group of rods is connected to group of optical nerves and hence accounts for overall perception.

12. The blind spot in the eye is entirely deprived of the light receptors, rods and cones.

Parts and functions of a Human Eye

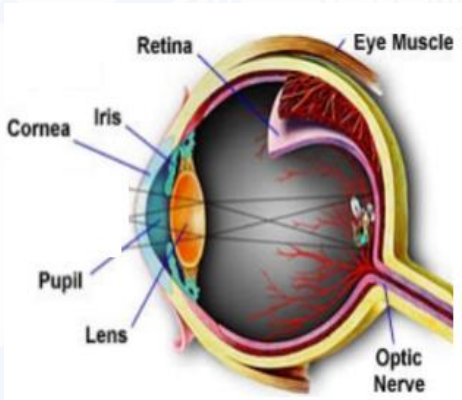
FYI

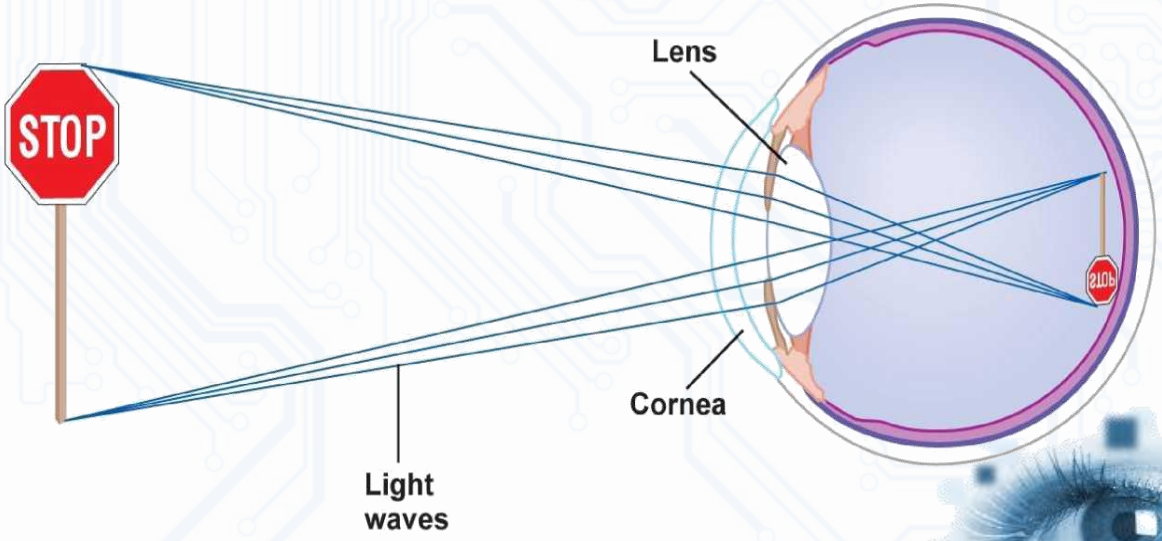
- The human eye is like a camera.
- Its lens forms an image on a light-sensitive screen called the retina.
- Light enters the eye through a thin membrane called the cornea.
- Cornea forms the transparent bulge on the front surface of the eyeball.
- The eyeball is approximately spherical in shape with a diameter of about 2.3 cm.
- Most of the refraction of light rays entering the eye occurs at the outer surface of the cornea.
- The crystalline lens merely provides the finer adjustment of focal length required to focus objects at different distances on the retina.
- Iris is a dark muscular diaphragm behind the cornea and it controls the size of the pupil.
- The pupil regulates and controls the amount of light entering the eye.
- The eye lens forms an inverted real image of the object on the retina.

- The eye lens is composed of a fibrous, jelly-like material.
- Its curvature can be modified to some extent by the ciliary muscles.
- The change in curvature can thus change the focal length of the lens.
- The retina is a delicate membrane having enormous number of light-sensitive cells.
- The light-sensitive cells get activated upon illumination and generate electric signals.
- These signals are sent to brain via optic nerves.
- The brain intercepts these signals and finally processes the information for our perception.

Your 2 Lenses: Cornea and Lens

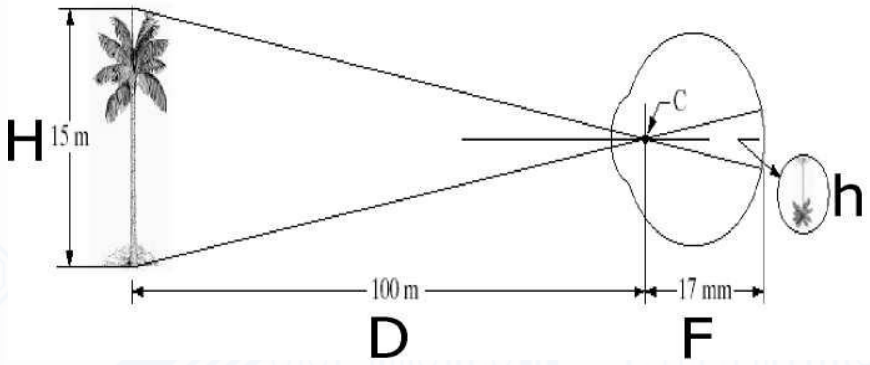
- There are two lenses in your eye, the cornea and the lens.
- The cornea, the front surface of the eye, does most of the focusing in your eye
- The lens provides adjustable fine-tuning of the focus
- Muscles in eye can change the shape of the lens allowing us focus on near or far objects
- An image is focused onto retina exciting the rods and cones and send signals to the brain





Elements of visual perception

视觉感知要素 Shìjué gǎnzhī yàosù



$$\frac{H}{D}=\frac{h}{F}\Rightarrow h=\left(\frac{H}{D}\right)\times F$$

- The distance between the center of the lens and the retina, called the **focal length**, varies from approximately 17 mm to about 14 mm. 焦距 Jiāojù

高度 Gāodù

- The height, h of an object of **height**, H perceived by an observer, having a focal length, F, from a distance, D is given by the principle of similar triangle. 距离 Jùlí

FUNCTIONS: How Your Lens Focuses

Your lens has a small depth of field

- You can't see something close and far with both objects in focus at the same time
- **Hold out your thumb about a foot away from your eye**
- Then, alternately focus on thumb and me (right above your thumb)

• Note that you cannot see *both* me *and* your thumb sharply (in focus) at the same time

You focus on one or the other by changing the bulge of your lens

Brightness Adaptation of Human Eye

Because digital images are displayed as a discrete set of intensities, the eye's ability to discriminate between different intensity levels is an important consideration in presenting image-processing results

主观亮度 Zhǔguān liàngdù

- **Subjective brightness** is a logarithmic function of incident light intensity.
- The human visual system can perceive approximately 10^{10} different light intensity levels
- However, at any one time we can only discriminate between a much smaller number - *brightness adaptation*
- Similarly, *perceived intensity* of a region is related to the light intensities of the regions surrounding it

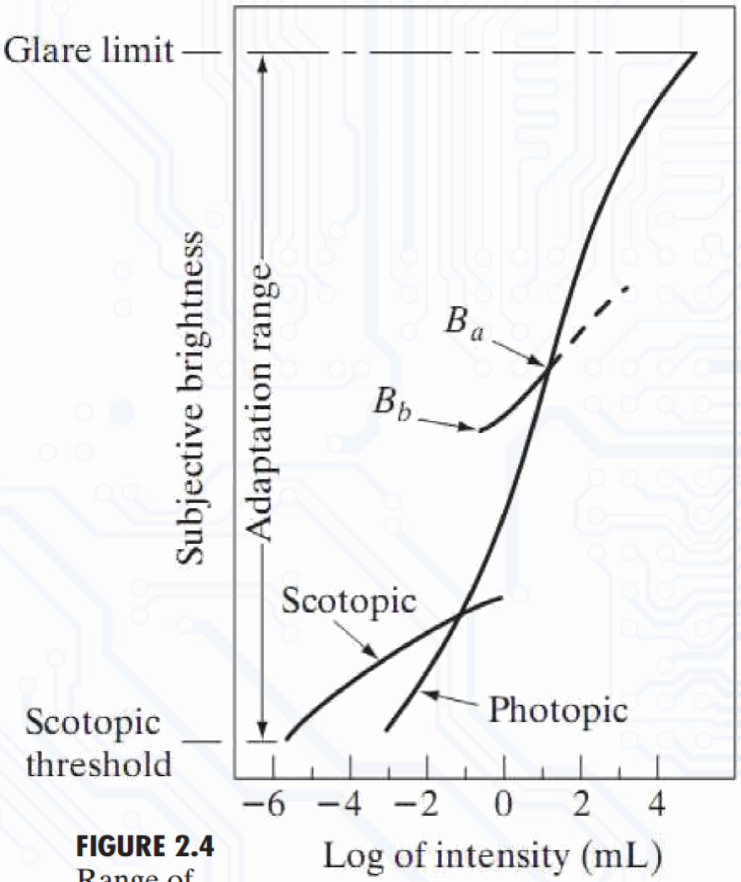


FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

Brightness Adaptation and Discrimination

亮度适应与辨别 Liàngdù shìyìng yǔ biànbié

Experimental evidence indicates that subjective brightness (intensity as perceived by the human visual system) is a logarithmic function of the light intensity incident on the eye

在(zài)解释(jiěshì)图(tú)2.4所(suǒ)示(shì)的(de)令人(lìngrén)印象(yìnxiàng)深刻(shēnkè)的(de)动态范围(dòngtàifànwéi)时(shí)，关键(guānjiàn)的(de)一点(yìdiǎn)是(shì)视觉(shìjué)系统(xìtǒng)不能(bùnéng)同时(tóngshí)这样(zhèyàng)的(de)范围(fànwéi)内(nèi)运行(yùnxíng)

The essential point in interpreting the impressive dynamic range depicted in Fig. 2.4 is that the visual system cannot operate over such a range *simultaneously*.

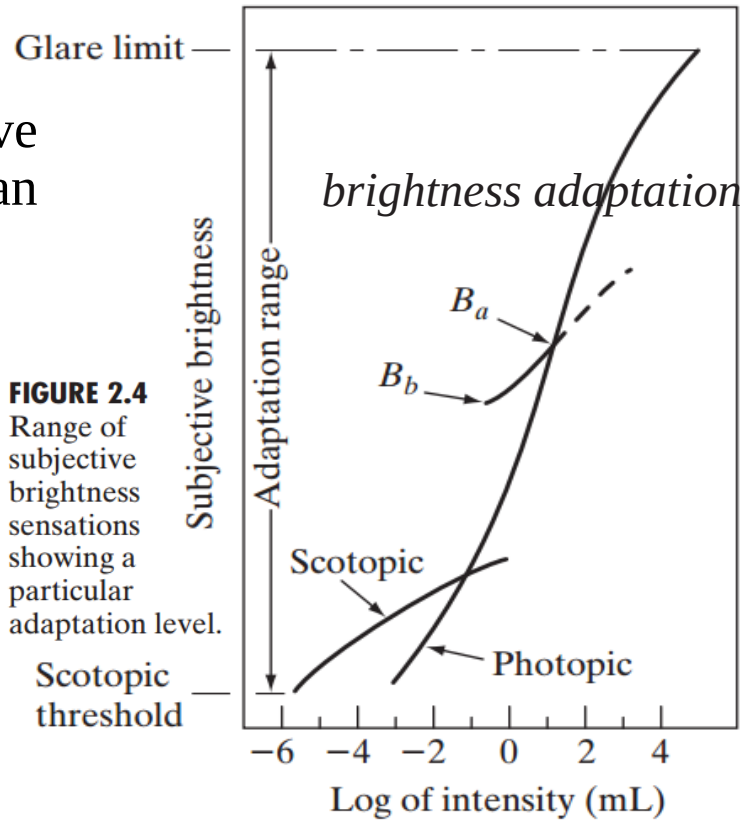


FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

Brightness Adaptation and Discrimination

- that the eye is capable of detecting objectionable contouring effects in monochrome images whose overall intensity is represented by fewer than approximately two dozen levels.

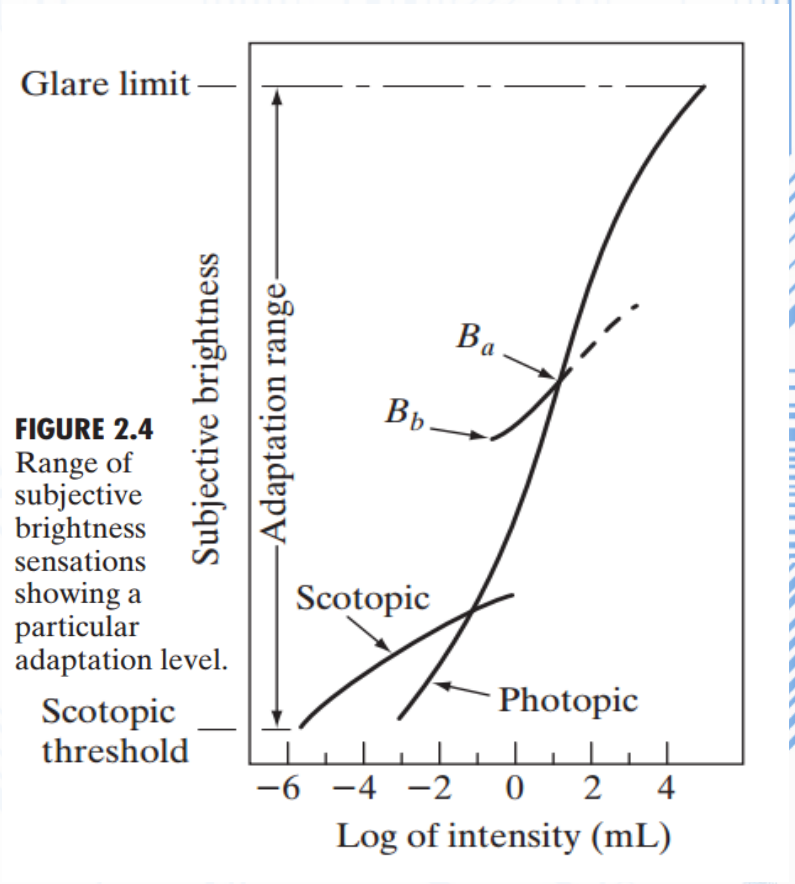


FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

Brightness…..

- Two phenomena clearly demonstrate that perceived brightness is not a simple function of intensity.

- The first is based on the fact that the visual system tends to undershoot or overshoot around the boundary of regions of different intensities.

  These seemingly scalloped bands are called *Mach bands* after Ernst Mach, who first described the phenomenon in 1865.

- The second phenomenon, called **simultaneous contrast**, is related to the fact that a region's perceived brightness does not depend simply on its intensity.

这些看似扇形的波带被称为马赫波带，以恩斯特.马赫的名字命名的，马赫在1865年首次描述了这一现象。

Brightness Adaptation of Human Eye

人眼亮度自适应 Rén yǎn liàngdù zì shìyìng

- The **brightness adaptation** is a phenomenon which describes the ability of the human eye in simultaneously discriminating distinct intensity levels.

人眼同时区分不同强度水平的能力。
Rén yǎn tóngshí qūfēn bùtóng qiángdù shuǐpíng de nénglì.

- The **brightness adaptation level** is the current sensitivity level of the visual system for any given set of conditions.

同时对比 Tóngshí duìbǐ

- The **simultaneous contrast** is a phenomenon which describes that the perceived brightness of a region in an image is not a simple function of its intensity rather it depends on the intensities of neighbouring regions.

Brightness Adaptation of Human Eye

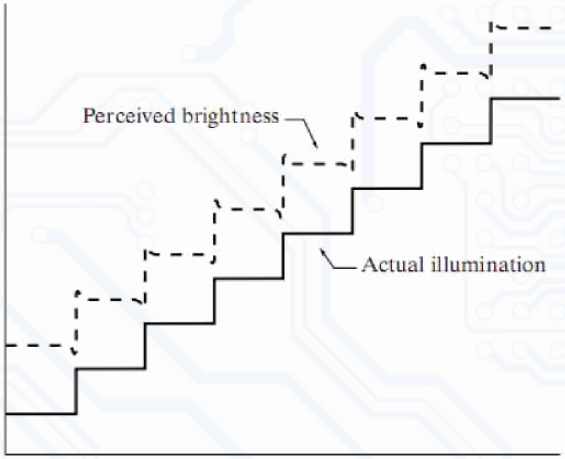
undershoot or overshoot around the boundary

边界周围下冲或过冲

Biānjiè zhōuwéi xià chōng huòguò chōng

- The ability of the eye to discriminate between changes in light intensity at any specific adaptation level is also of considerable interest.
- Figure 2.7(a) shows a striking example of this phenomenon. Although the intensity of the stripes is constant, we actually perceive a brightness pattern that is strongly scalloped, especially near the boundaries [Fig. 2.7(b)].

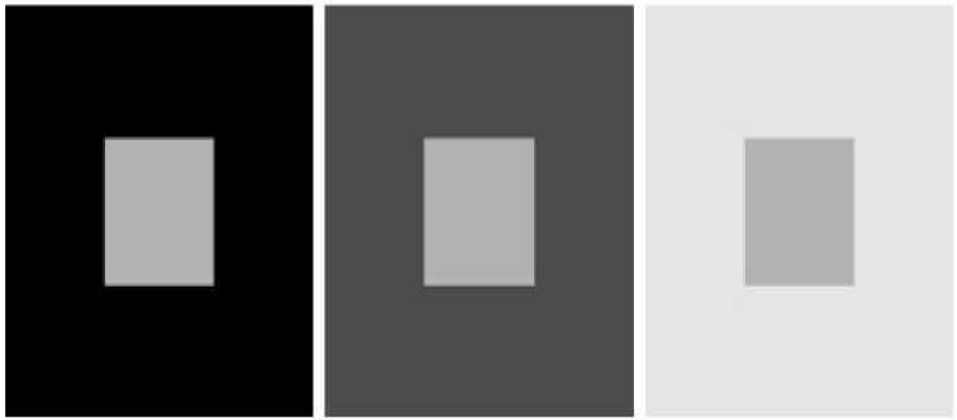
  These seemingly scalloped bands are called Mach bands after Ernst Mach, who first described the phenomenon in 1865.



Brightness Adaptation of Human Eye

simultaneous contrast, 比赛乐队 Bǐsài yuèduì

The **match bands** are the adjacently spaced rectangular stripes of constant intensities to demonstrate the phenomenon of simultaneous contrast.



Examples of simultaneous contrast.
All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

所有内部的正方形都有相同的强度，但是随着背景变浅，它们的颜色逐渐变深。

The second phenomenon, called *simultaneous contrast*, is related to the fact that a region's perceived brightness does not depend simply on its intensity, as Fig. 2.8 demonstrates. All the center squares have exactly the same intensity.

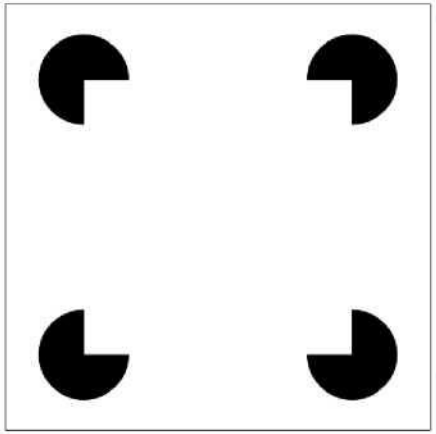
A more familiar example is a piece of paper that seems white when lying on a desk, but can appear totally black when used to shield the eyes while looking directly at a bright sky

Optical illusion

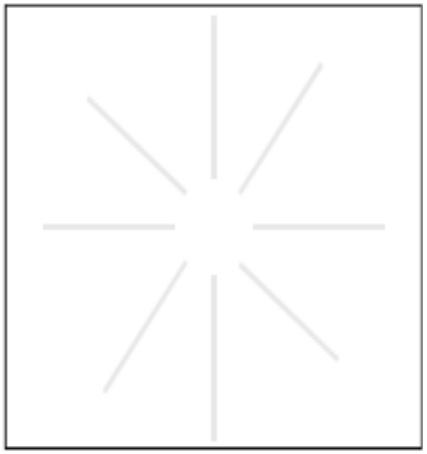
光学错觉 Guāngxué cuòjué

Other examples of human perception phenomena are optical illusions, in which the eye fills in nonexisting information or wrongly perceives geometrical properties of objects.

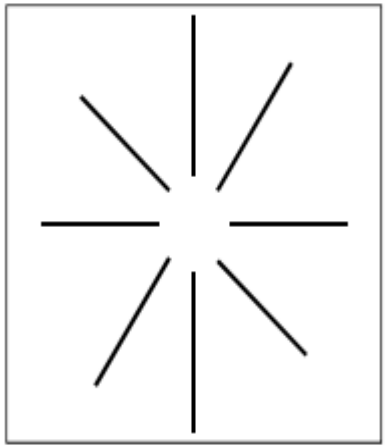
In this the eye fills the non existing information or wrongly pervious geometrical properties of objects



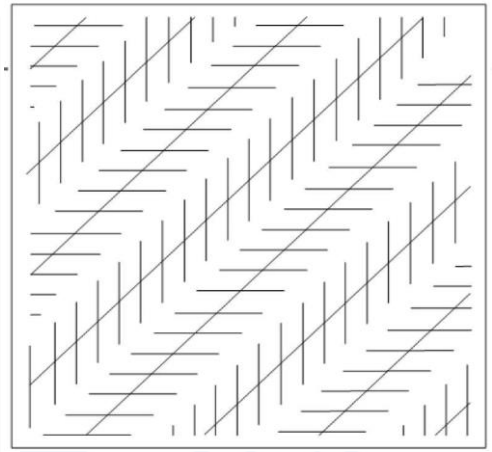
Illusion of a white square



Illusion of a white circle



Illusion of a white circle



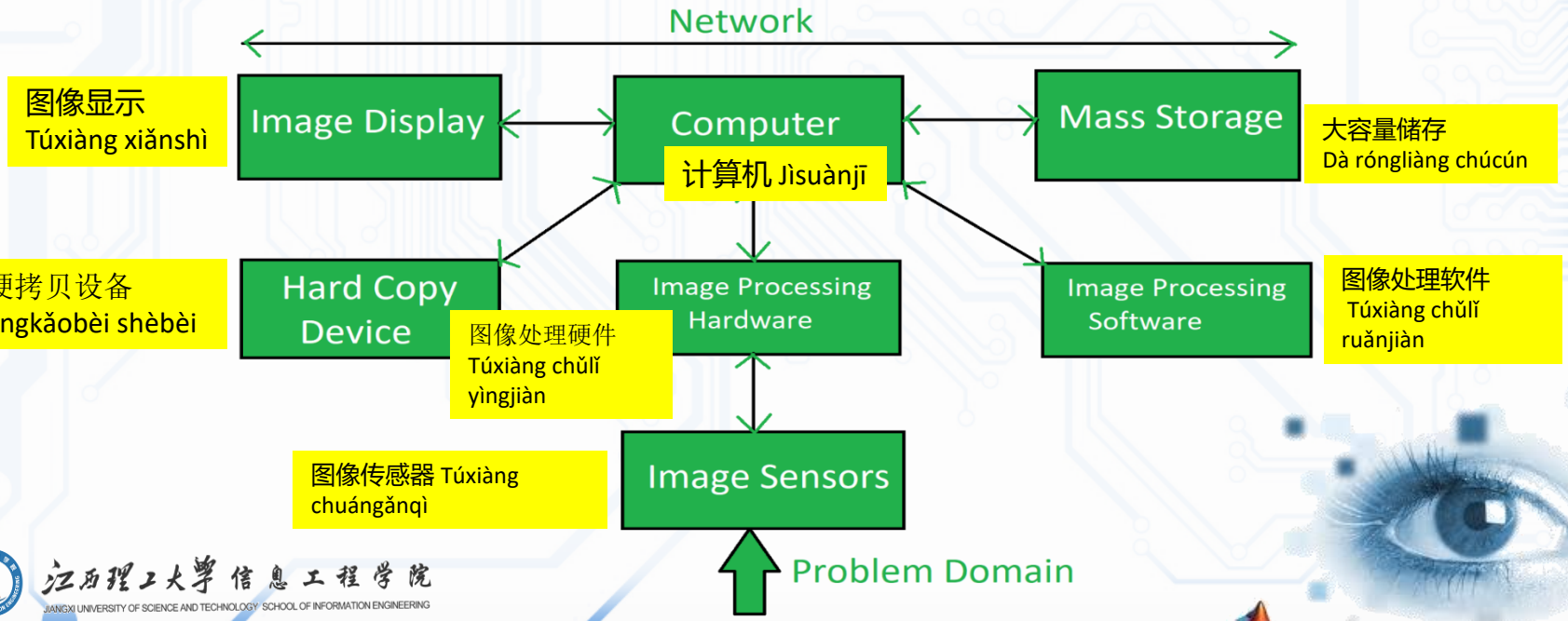
Illusion of loss of parallelism & coplanarity

Components of an Image Processing System

图像处理系统的组成部分 Túxiàng chǔlǐ xìtǒng de zǔchéng bùfèn

Image Processing System is the combination of the different elements involved in the digital image processing.

- Digital image processing is the processing of an image by means of a digital computer.
- Digital image processing uses different computer algorithms to perform image processing on the digital images.



Components of an Image Processing System

•Image Sensors:

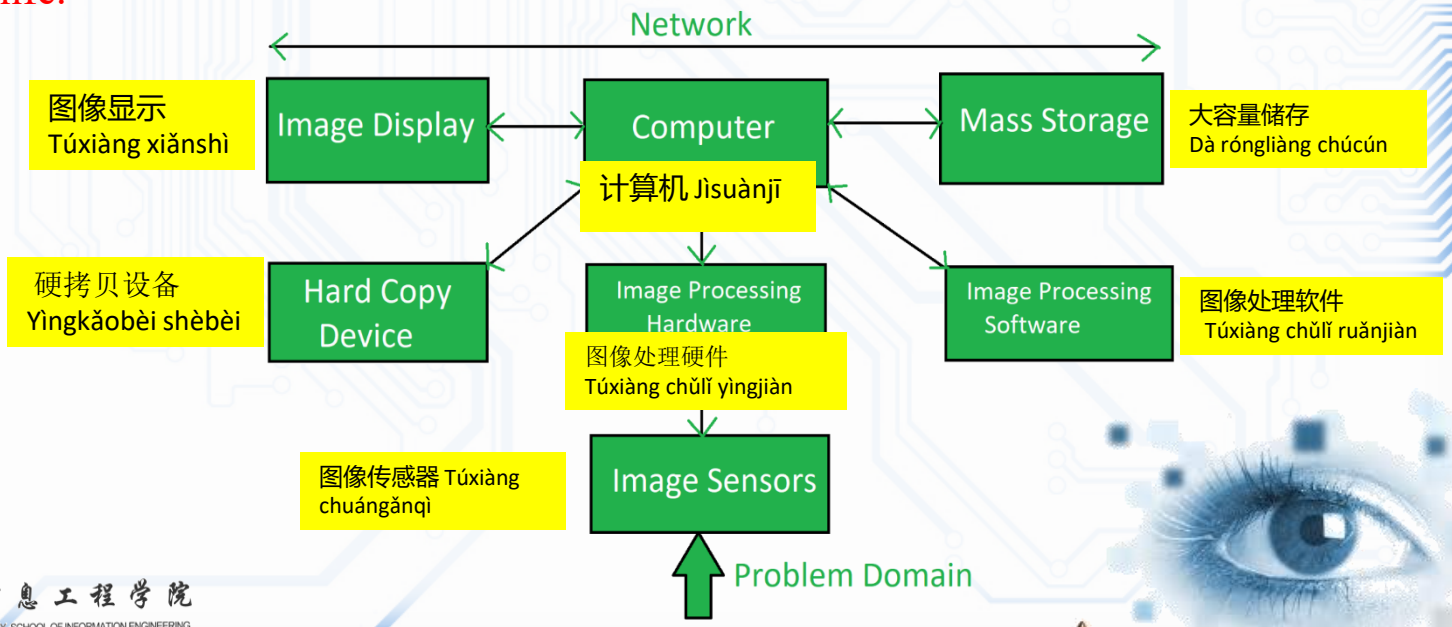
Image sensors senses the intensity, amplitude, co-ordinates and other features of the images and passes the result to the image processing hardware. It includes the problem domain.

•Image Processing Hardware:

Image processing hardware is the dedicated hardware that is used to process the instructions obtained from the image sensors. It passes the result to general purpose computer.

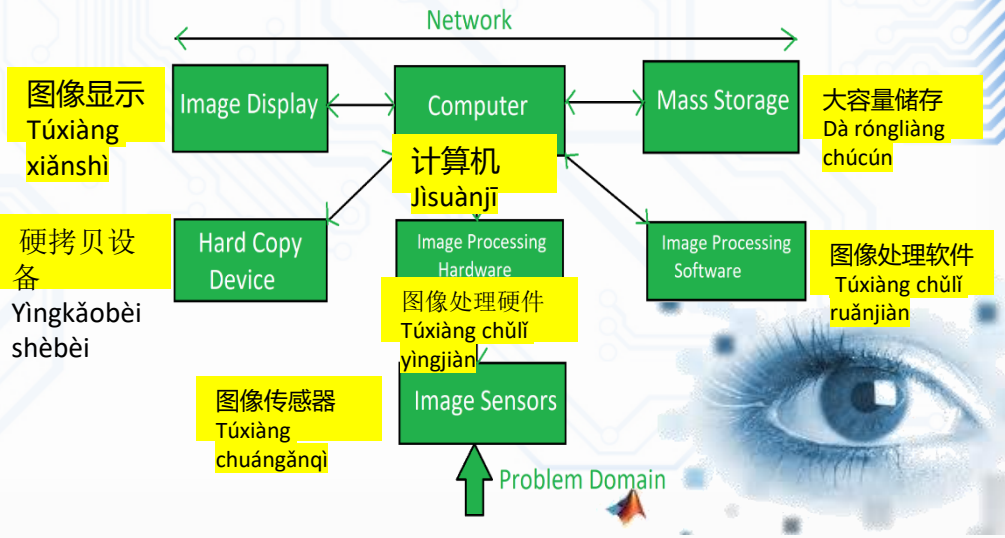
•Computer:

Computer used in the image processing system is the general purpose computer that is used by us in our daily life.



Components of an Image Processing System

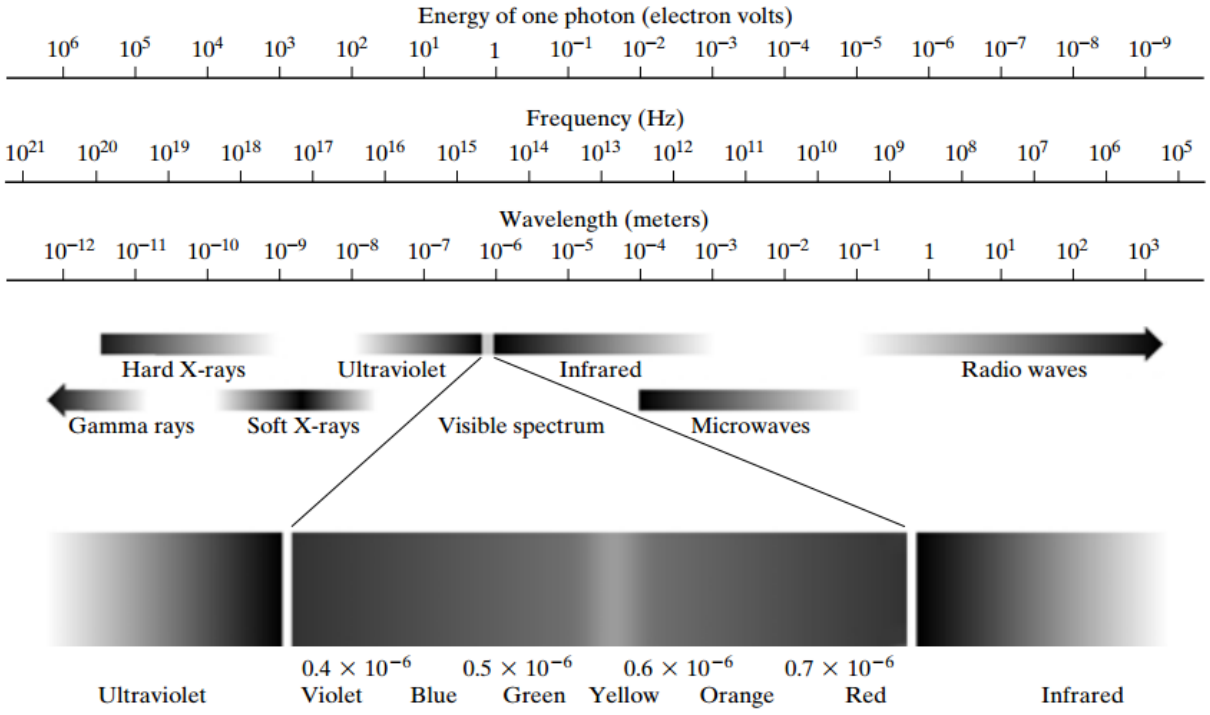
- **Image Processing Software:**
  Image processing software is the software that includes all the mechanisms and algorithms that are used in image processing system.
- **Mass Storage:**
  Mass storage stores the pixels of the images during the processing.
- **Hard Copy Device:**
  Once the image is processed then it is stored in the hard copy device. It can be a pen drive or any external ROM device.
- **Image Display:**
  It includes the monitor or display screen that displays the processed images.
- **Network:**
  Network is the connection of all the above elements of the image processing system



Light And The Electromagnetic Spectrum

光与电磁频谱 Guāng yǔ diàncí pínpǔ

Light: just a particular part of electromagnetic spectrum that can be sensed by the human eye. The electromagnetic spectrum is split up according to the wavelengths of different forms of energy

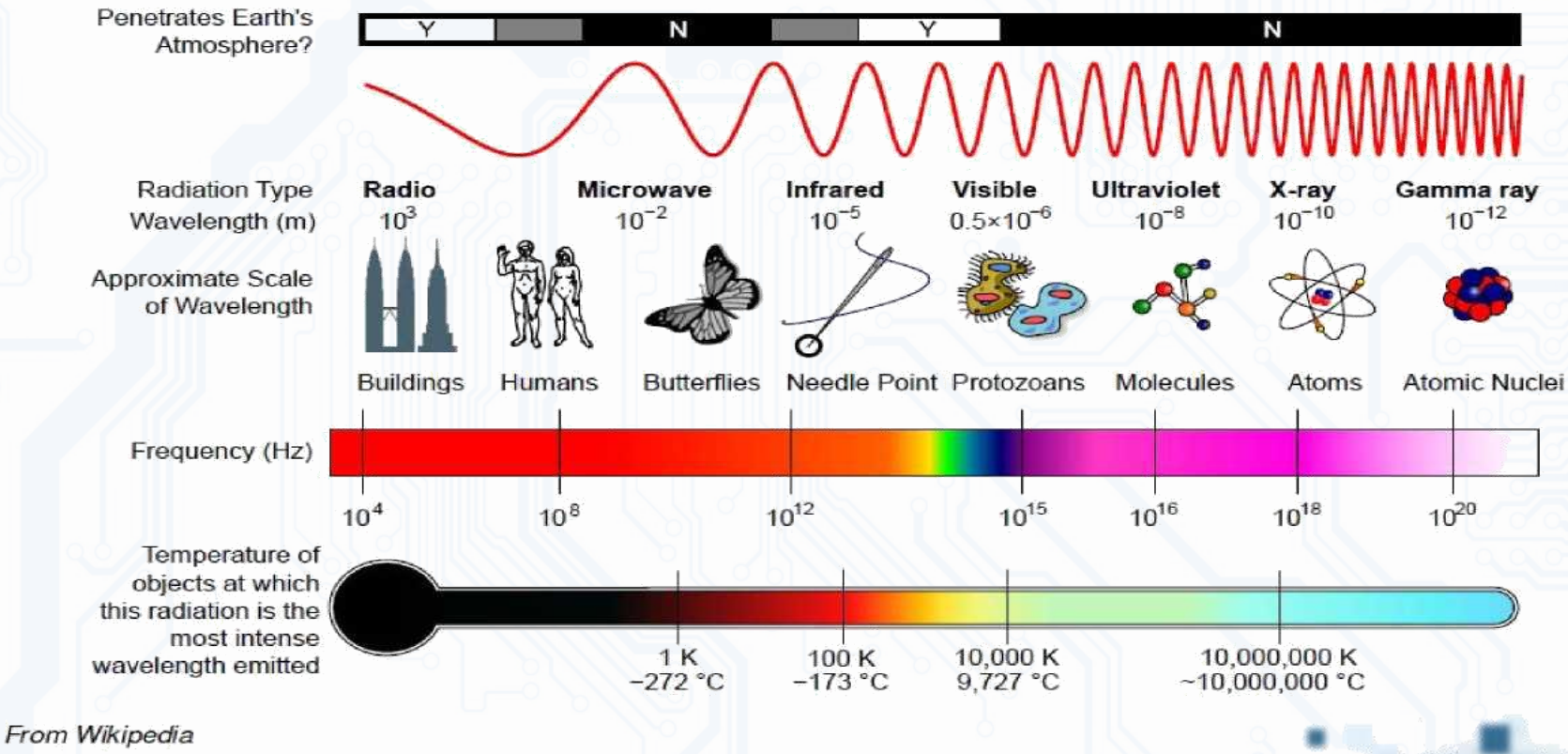


Frequency (Hz)
Energy of one photon (electron volts)
Wavelength (meters)
Radio waves
Microwaves
Ultraviolet Infrared
Gamma rays
Soft X-rays
Visible spectrum
Hard
X-rays
Ultraviolet
Violet
Blue
Green
Yellow
Red
Orange
Infrared

Electromagnetic Spectrum and IP :

电磁频谱和 IP : Diàncí pínpǔ hé IP:

Images can be made from any form of EM radiation



From Wikipedia

Light and EM Spectrum

Monochromatic light: void of color

Intensity is the only attribute, from black to white

Monochromatic images are referred to as **gray-scale** images

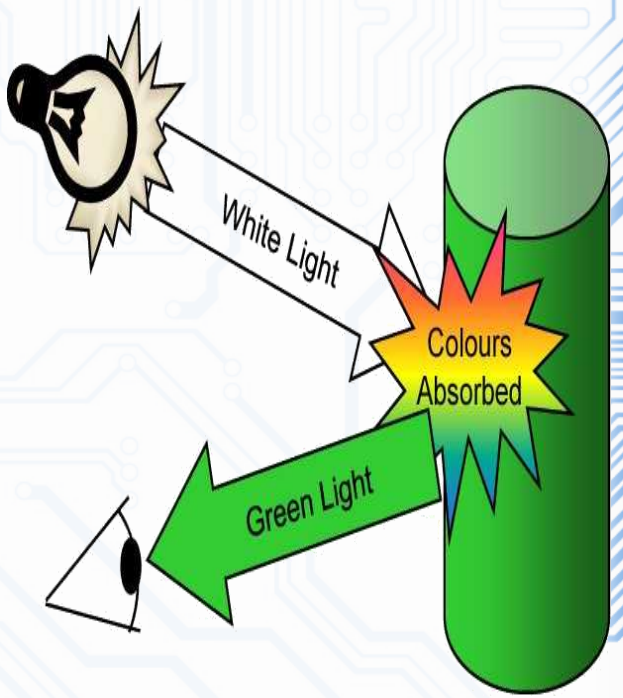
Chromatic light bands: ***0.43 to 0.79 um***

The quality of a chromatic light source:

1. **Radiance:** total amount of energy
2. **Luminance (lm):** the amount of energy an observer perceives from a light source
3. **Brightness:** a subjective descriptor of light perception that is impossible to measure. It embodies the achromatic notion of intensity and one of the key factors in describing color sensation.

Reflected Light (Light and EM Spectrum)

- The colours humans perceive are determined by nature of light reflected from an object.
- For example, if white light (contains all wavelengths) is shone onto green object it absorbs most wavelengths absorbed except green wavelength (color)



Some Typical Ranges of Reflectance

一些典型的反射范围
Yīxiē diǎnxíng de fǎnshè fànwéi

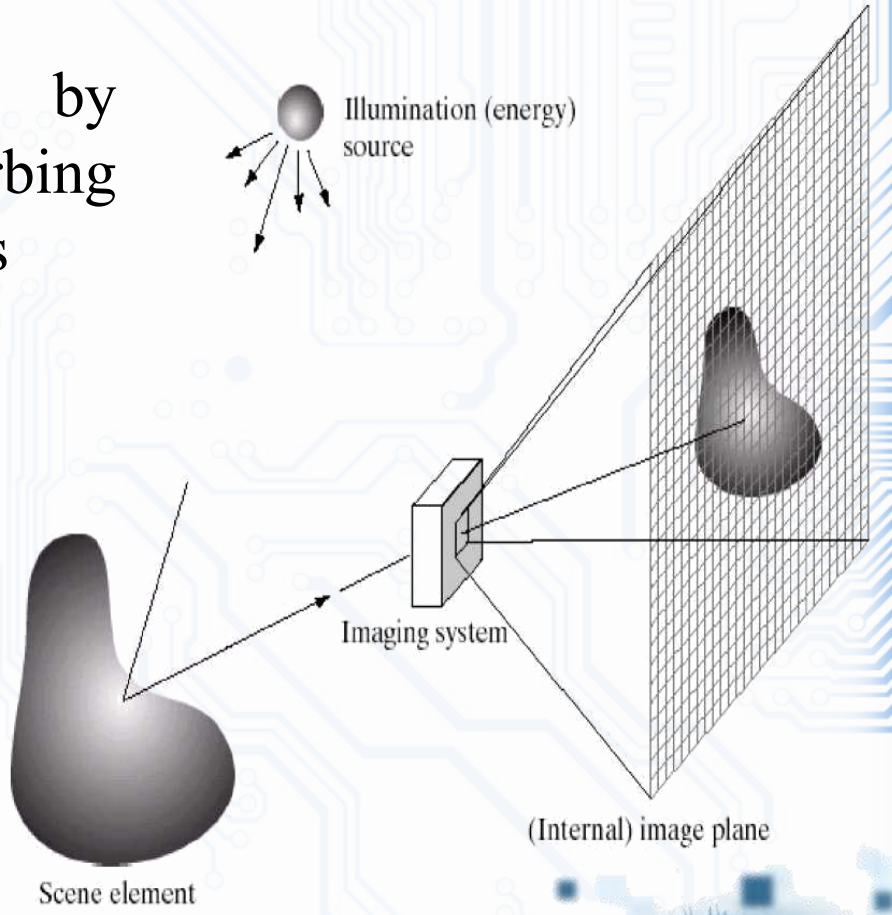
- Reflectance 反射率 Fǎnshè lǜ
  - 0.01 for black velvet
  - 0.65 for stainless steel
  - 0.80 for flat-white wall paint
  - 0.90 for silver-plated metal
  - 0.93 for snow

Image Acquisition

图像采集 Túxiàng cǎijí

•Images typically generated by *illuminating a scene* and absorbing energy reflected by scene objects

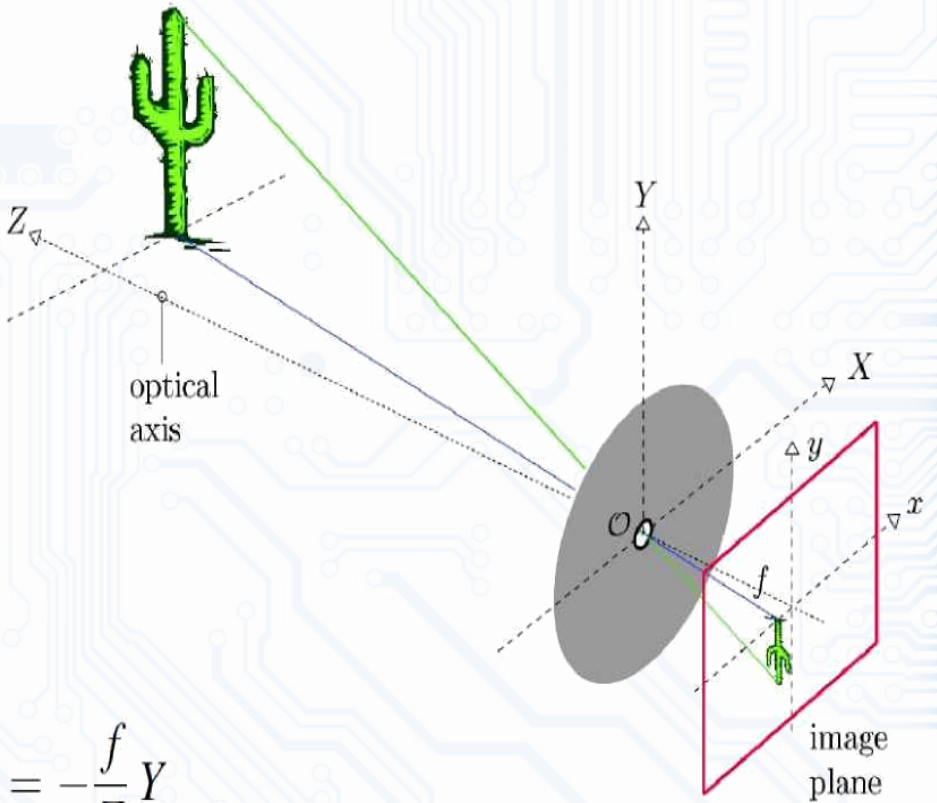
•通常通过照亮场景并吸收场景对象反射的能量而生成的图像
•Tōngcháng tōngguò zhào liàng chǎngjǐng bìng xīshōu chǎngjǐng duìxiàng fǎnshè de néngliàng ér shēngchéng de túxiàng



The Pinhole Camera

针孔相机 Zhēn kǒng xiàngjī

- First described by ancient Chinese and Greeks (300-400AD)



$$x = -\frac{f}{Z}X, \qquad y = -\frac{f}{Z}Y$$

Thin Lens

薄镜片 Báo jìngpiàn

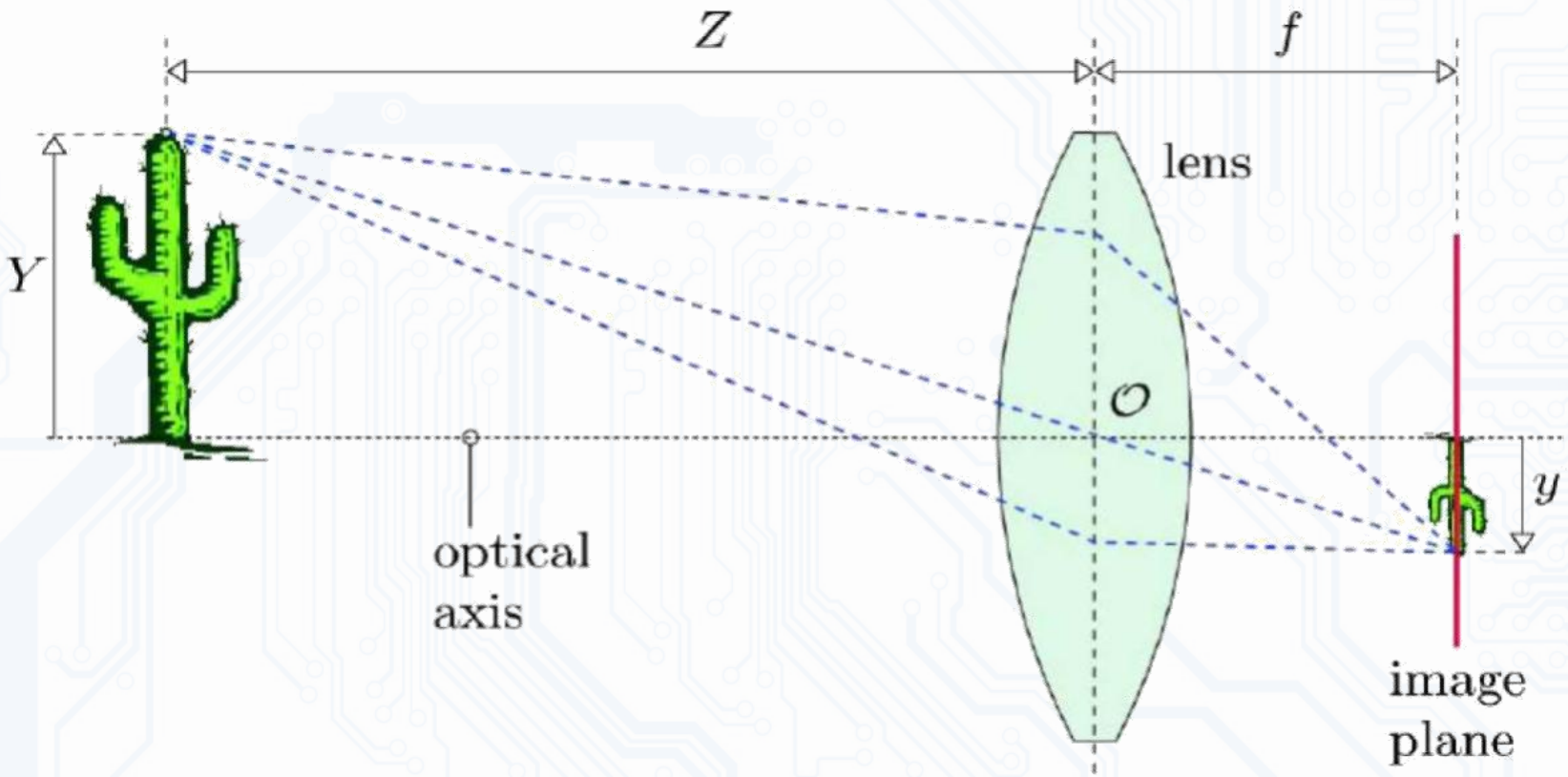


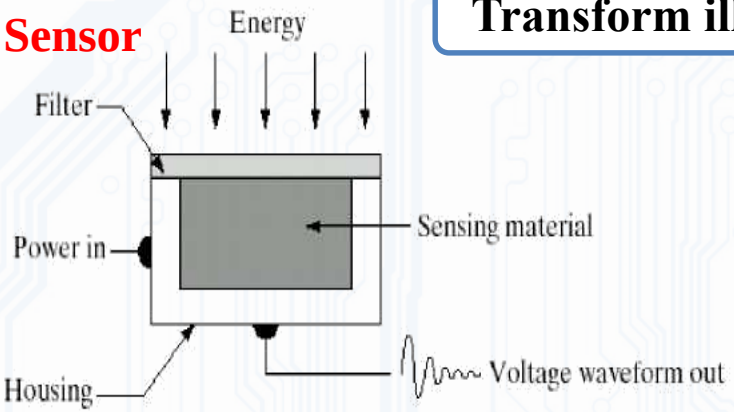
Image Sensing

图像传感 Túxiàng chuán gǎn

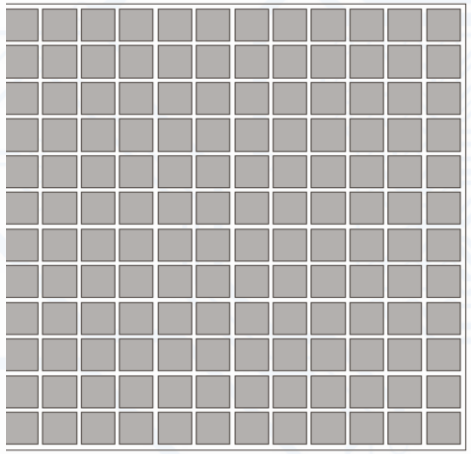
- Incoming energy (e.g. light) lands on a sensor material responsive to that type of energy, generating a voltage
- Collections of sensors are arranged to capture images

Transform illumination energy into digital images

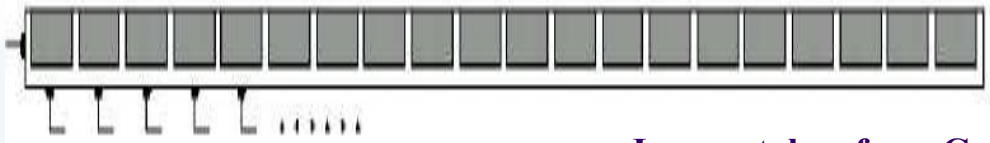
Imaging Sensor



Array of Image Sensors



Line of Image Sensors



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Acquisition Using a Single Sensor

使用单个传感器的图像采集
Shǐyòng dāngè chuángǎnqì de túxiàng cǎijí

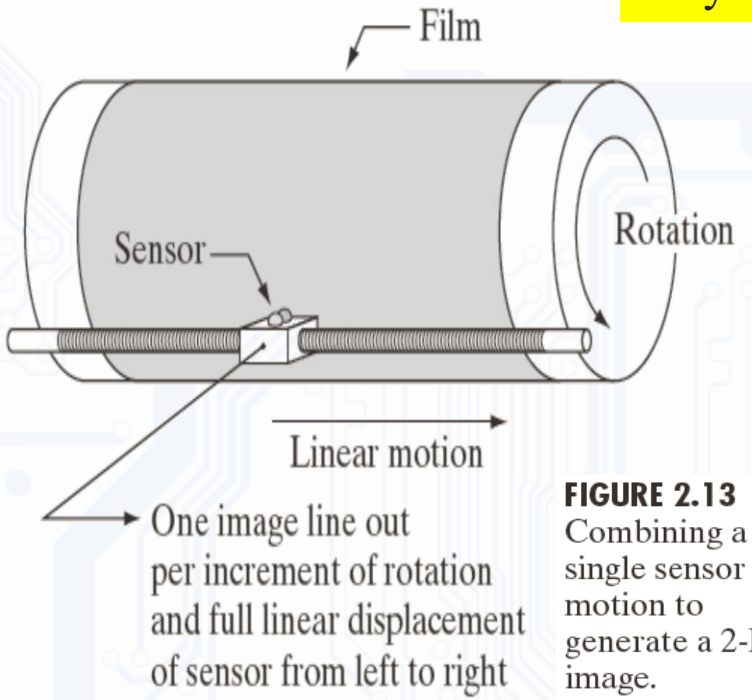


FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

Figure 2.13 shows an arrangement used in high-precision scanning, where a film negative is mounted onto a drum whose mechanical rotation provides displacement in one dimension.

Image Acquisition Using Sensor Strips

使用传感器条进行图像采集
Shǐyòng chuángǎnqì tiáo jìnxíng túxiàng cǎijí

Fig. 2.14(a).This is the type of arrangement used in most flat bed scanners. Sensing devices with 4000 or more in-line sensors are possible.

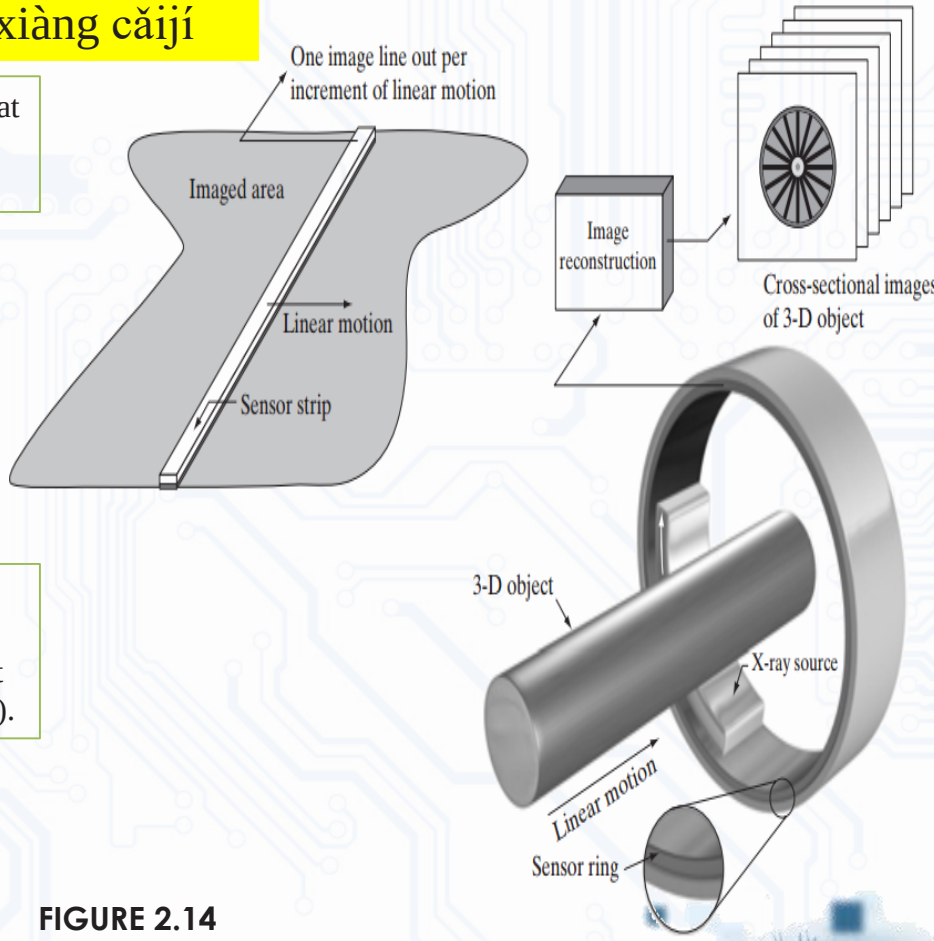


Fig. 2.14(b) shows. A rotating X-ray source provides illumination and the portion of the sensors opposite the source collect the X-ray energy that pass through the object (the sensors obviously have to be sensitive to X-ray energy).

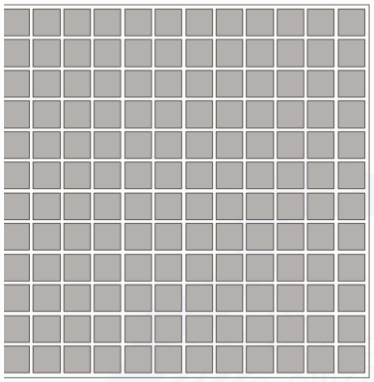
FIGURE 2.14
(a) Image acquisition using a linear sensor strip.
(b) Image acquisition using a circular sensor strip.

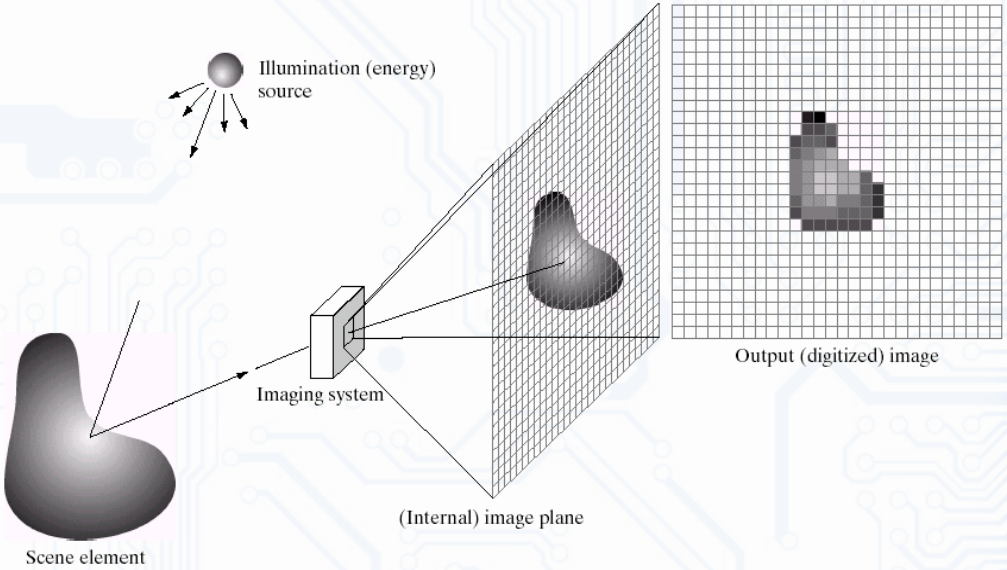
Image Acquisition Using Sensor Arrays

Array of Image Sensors

使用传感器阵列进行图像采集

Shǐyòng chuángǎnqì zhènliè jìnxíng túxiàng cǎijí





a b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

the energy from an illumination source being reflected from a scene element, but, as mentioned at the beginning of this section, the energy also could be transmitted through the scene element

来自光源的能量被场景元素反射，但是如前所述1在这段的开始，能量也是0，可以通过强硬的场景元素传递。

collect the incoming energy and focus it onto an image plane. If the illumination is light, the front end of the imaging system is a lens, which projects the viewed scene onto the lens focal plane,

搜集进来的能量，集中在图像平面。如果照明很亮，就在前面成像系统的末端是一个透镜，它将观察到的场景投射到焦平面上

Simple Image Model

简单的图像模型 Jiǎndān de túxiàng mú xíng

- An (monochrome or black & white) image is a 2-D light-intensity function denoted as **f(x,y)**.
- The value or amplitude, f of the function at any spatial coordinates (x,y) is the intensity of the image at that point.

A Simple Image Formation Model

一个简单的图像形成模型 Yīgè jiǎndān de túxiàng xíngchéng móxíng

- When an image is generated from a physical process, its values are proportional to energy radiated by a physical source (e.g., electromagnetic waves).
- As a consequence, f(x, y) must be nonzero and finite; that is, $0<f(x, y)<\infty$.
- The two functions combine as a product to form f(x, y):

$$f(x, y)=i(x, y)r(x, y)$$

illumination $0<i(x, y)<q$

reflectance $0<r(x, y)<1.$

As light is energy, this value is non-zero and finite i.e.,$0 < f < \infty$ f(x,y) has two components:

(i) **i(x,y)**, the amount of light incident on the scene being viewed

(ii) **r(x,y)**, the reflectance relating to the amount of light reflected by the objects in the scene i.e.,

f(x,y) = i(x,y) r(x,y) where $0 < i < \infty$ & $0 \le r \le 1$

(Monochrome) Image

（单色）图像 (Dān sè) túxiàng

- For a monochrome image the intensity of the image, f at any coordinates (x,y) is termed as **grey level**, *l* of the image at that point, i.e.,
- **L min < *l* < Lmax ⇒ 0 < *l* < L,**
- **0 → black & L → white**
- **Intermediate values → shades of grey or grey shades**

Some Typical Ranges of illumination

一些典型的照明范围
Yīxiē diǎnxíng de zhàomíng fànwéi

Illumination

Lumen — A unit of light flow or luminous flux

Lumen per square meter (lm/m^2) — The metric unit of measure for illuminance of a surface

- On a clear day, the sun may produce in excess of 90,000 lm/m^2 of illumination on the surface of the Earth.
- On a cloudy day, the sun may produce less than 10,000 lm/m^2 of illumination on the surface of the Earth.
- On a clear evening, the moon yields about 0.1 lm/m^2 of illumination
- The typical illumination level in a commercial office is about 1000 lm/m^2

Student Task_2: DIP

- What type of camera we have ?
- What's is CCTV camera ?

Send for Next lecture

- **Send On University MOOC system**

江西理工大学

Jiangxi University of Science and Technology

信息工程学院

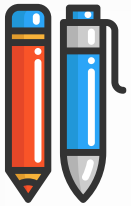
School of information engineering

Digital Image Processing

THANK YOU

"Reading allows you to travel, to make other people's experiences your own."

MARIO VARGAS LLOSA
Nobel Prize in Literature 2010



"BE HUMBLE. BE HUNGRY. AND ALWAYS BE THE HARDEST WORKER IN THE ROOM."