Pengolahan Citra - Pertemuan II – Image Formation

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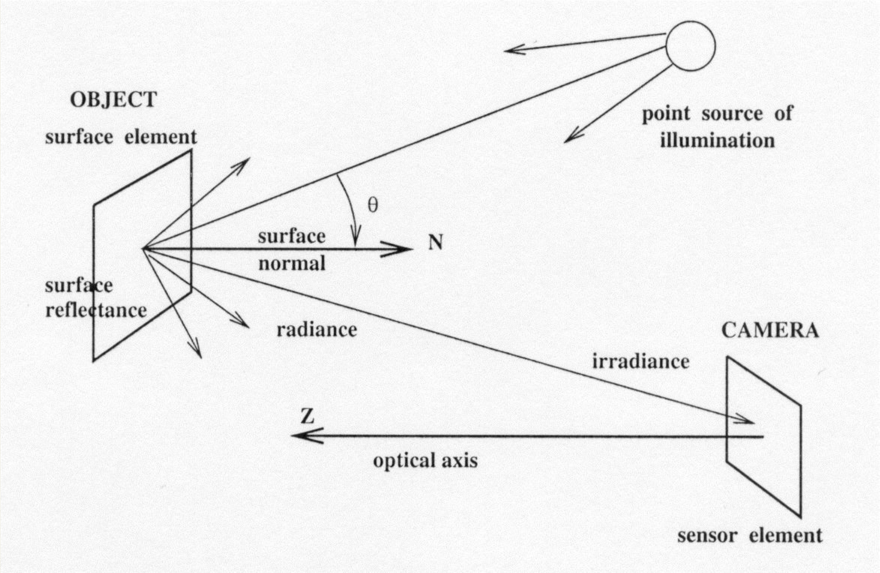
Materi:

1. Pengertian
2. Kamera
3. Aperture,DOF,Zoom
4. Visual Perception Human Eye
5. Kamera Digital
6. Kamera CCD
7. Kamera CMOS
8. Sampling
9. Kuantisasi
10. Tipe gambar
11. Format gambar

Model Sederhana dari Pembentukan Gambar

- Gambar diterangi oleh sumber
- Gambar mencerminkan radiasi ke arah kamera.
- Kamera mendeteksi melalui bahan kimia (film) atau sel-sel solid state (kamera CCD)



Dua Bagian Dari Proses Pembentukan Citra (*Image Formation*)

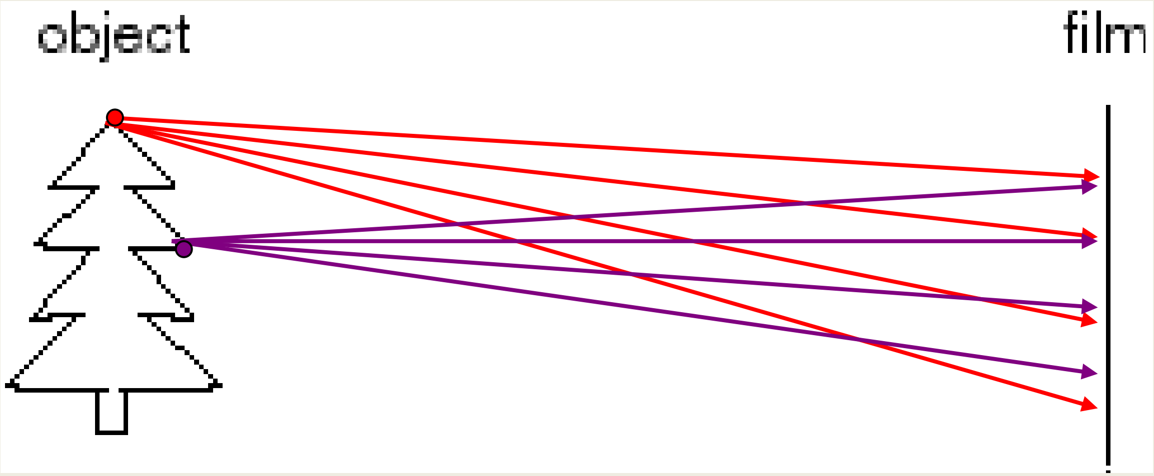
1. Pembentukan Citra secara Geometri adalah pembentukan citra yang menentukan di mana proyeksi piksel pada gambar akan ditempatkan di bidang gambar
2. Pembentukan Citra secara Fisika Cahaya adalah menentukan kecerahan suatu piksel pada bidang gambar sebagai fungsi penerangan dan sifat permukaan

Model Sederhana :

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

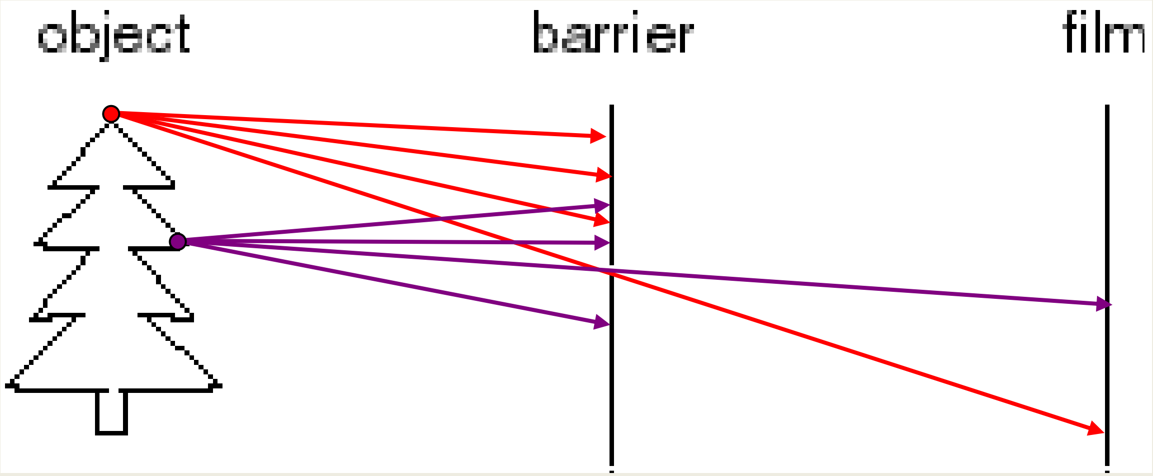
i: illumination, r: reflectance

Disain Kamera



- Tempatkan film di depan sebuah obyek
- Apakah kita akan mendapatkan gambar yang wajar ?
  - Blurring – Perlu lebih selektif!

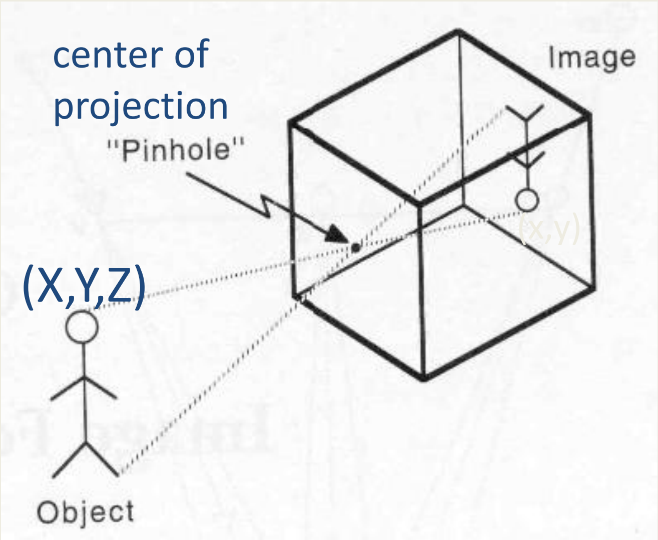
Disain Kamera (lanjutan)



- Tambahkan penghalang dengan lubang kecil (yaitu aperture) untuk memblokir sebagian besar sinar
  - Mengurangi blurring

Model Kamera “Pinhole”

- Perangkat sederhana untuk membentuk sebuah gambar 3D pada permukaan 2D.
- Sinar cahaya melewati “pinhole" dan membentuk sebuah gambar obyek yg terbalik pada bidang gambar



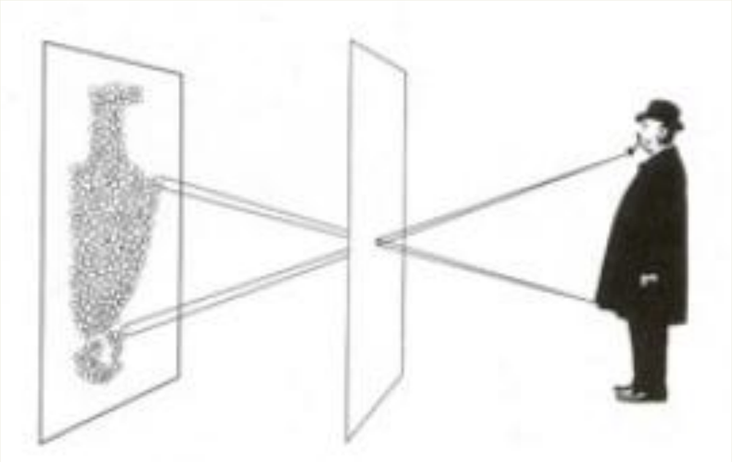
perspective projection:

$$x = \frac{fX}{Z} \quad y = \frac{fY}{Z}$$

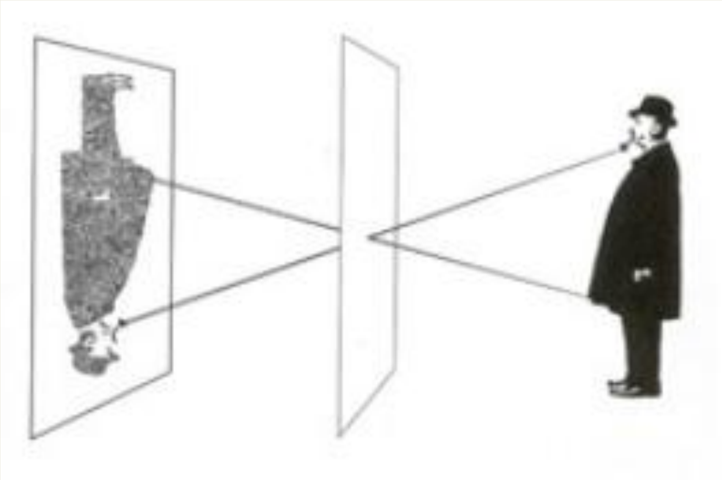
f: focal length

Apa pengaruh dari ukuran *aperture*?

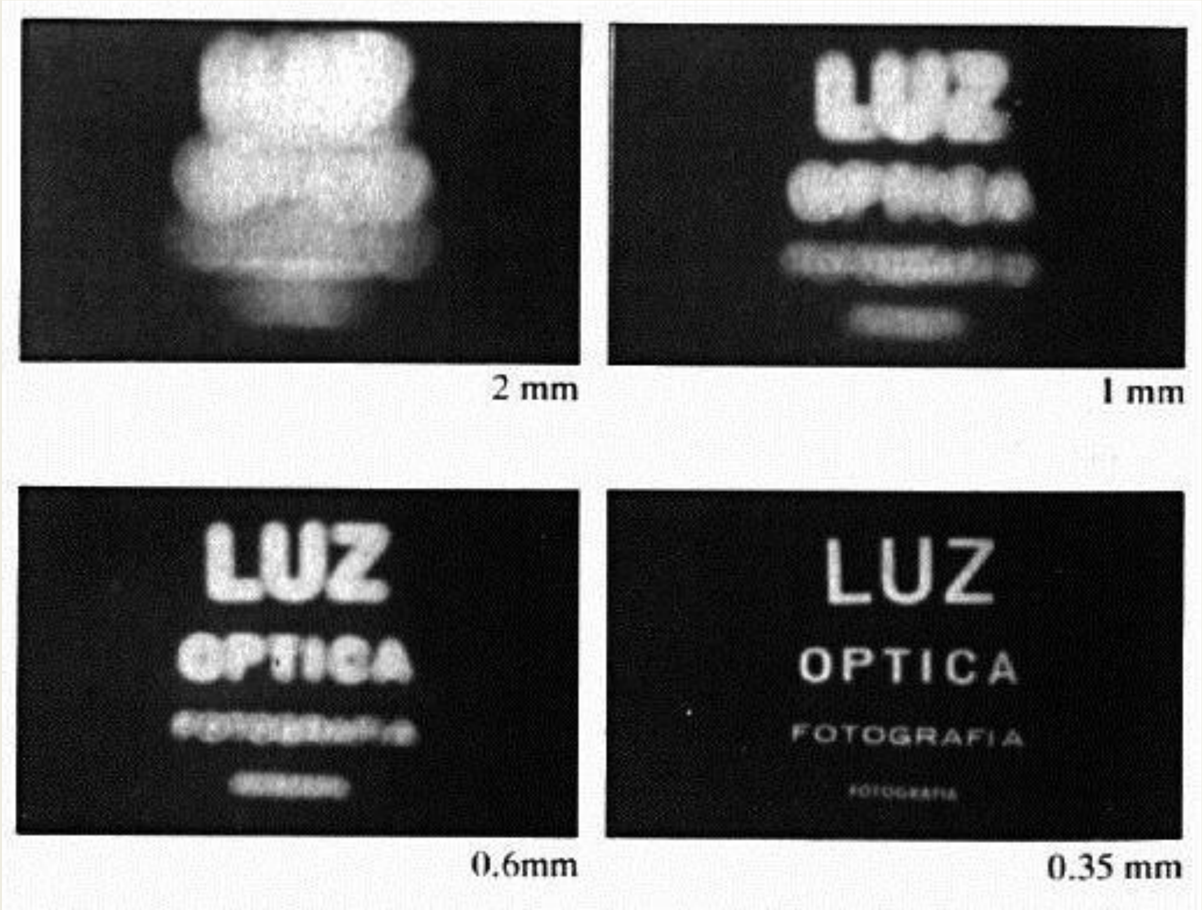
Aperture Besar: cahaya dari sumber menyebar di seluruh gambar (tidak terfokus dengan benar), membuatnya kabur !



Aperture kecil:
mengurangi blurring tetapi (i) membatasi jumlah cahaya yang masuk kamera dan (ii) menyebabkan difraksi cahaya.

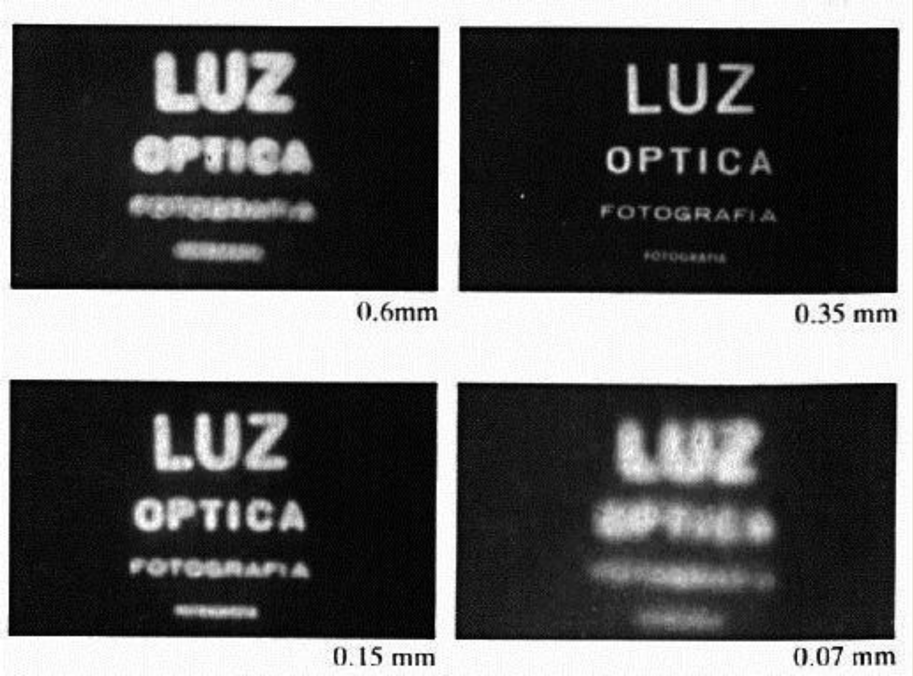


Contoh: Berbagai ukuran *aperture*



Contoh: Berbagai ukuran *aperture* (lanjutan)

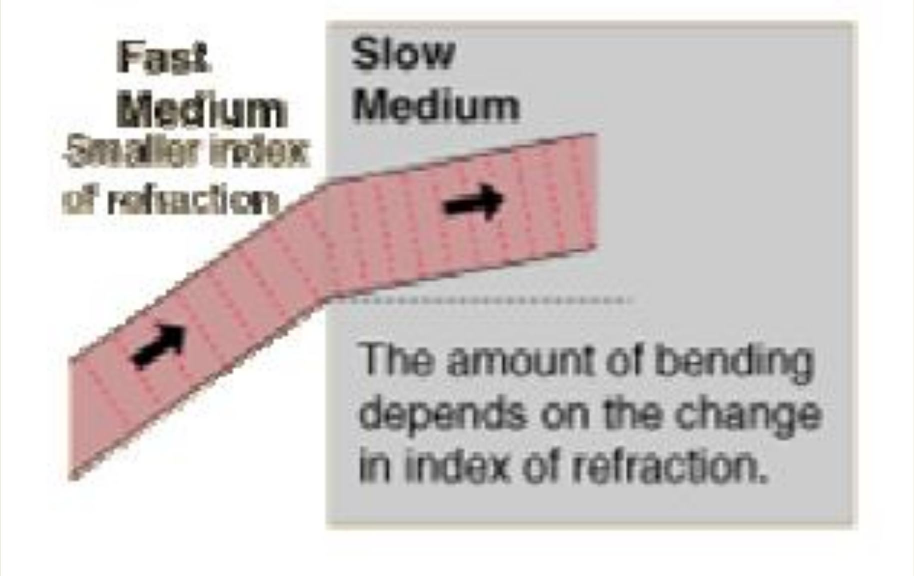
- Apa yang terjadi jika kita terus menurun ukuran aperture?
- Ketika cahaya melewati lubang kecil, tidak bepergian dalam garis lurus dan tersebar di berbagai arah (*difraksi*)



Solusi : refraksi

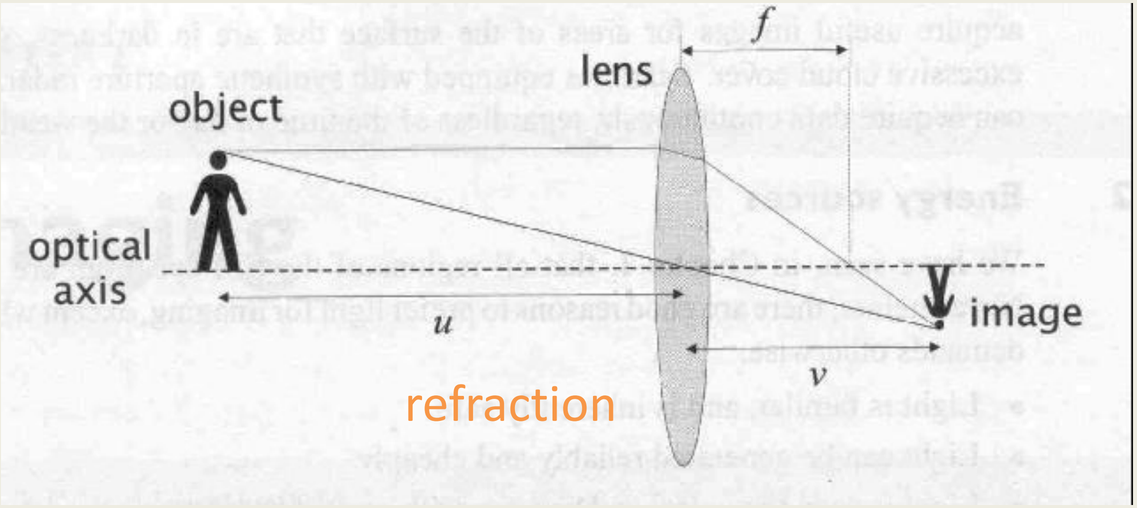
Refraksi

- Melenturkan gelombang ketika memasuki medium di mana kecepatan berbeda.



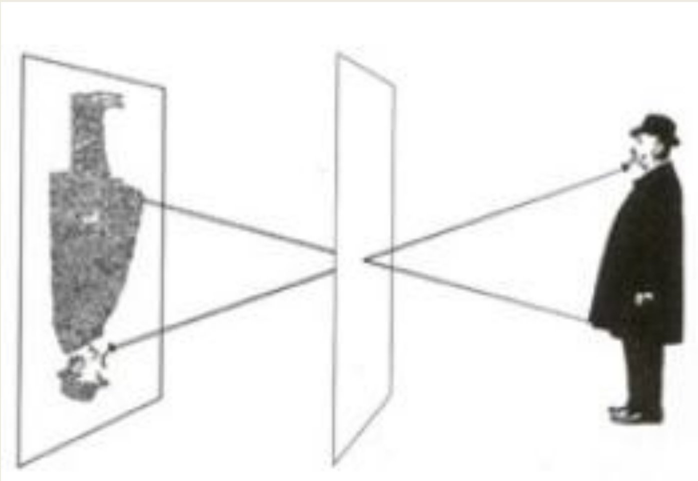
Lensa

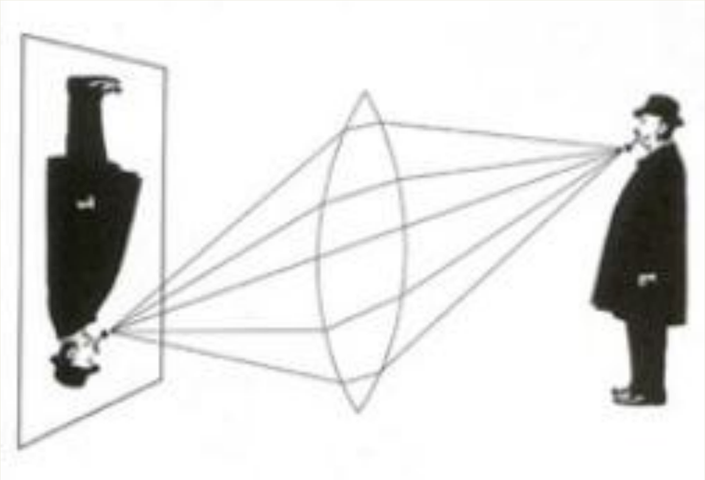
- Lensa meniru geometri *pinhole* tanpa menggunakan *aperture* kecil yang tidak diinginkan.
  - Mengumpulkan semua cahaya memancar dari titik objek terhadap *aperture* lensa yang terbatas.
  - Membawa cahaya menjadi fokus pada titik gambar ideal.



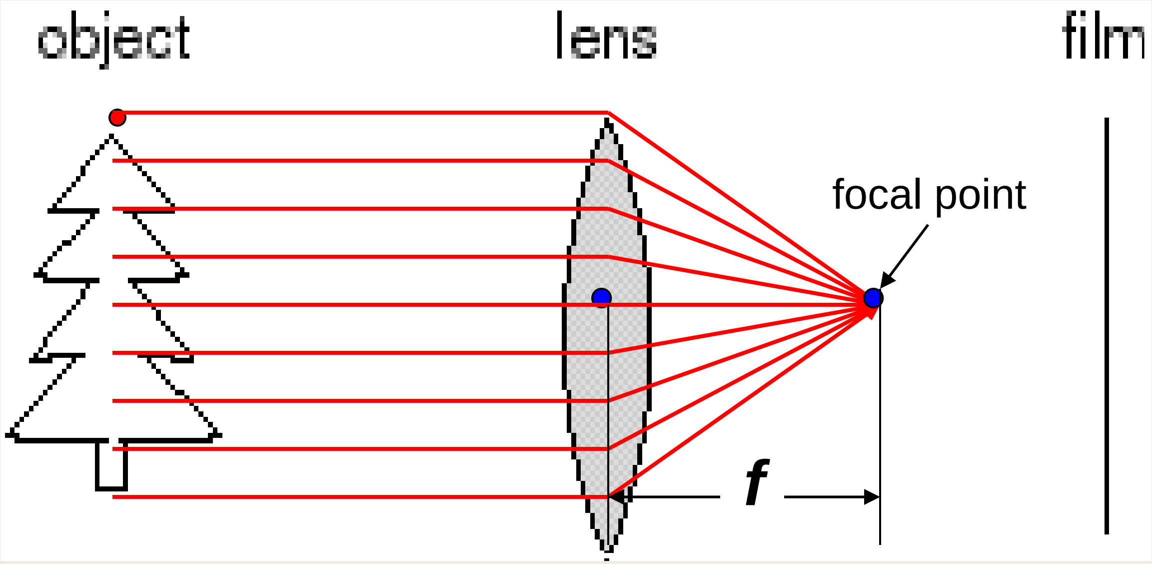
Lensa(lanjutan)

- Lensa meningkatkan kualitas gambar, yang mengarah ke gambar yang lebih tajam.



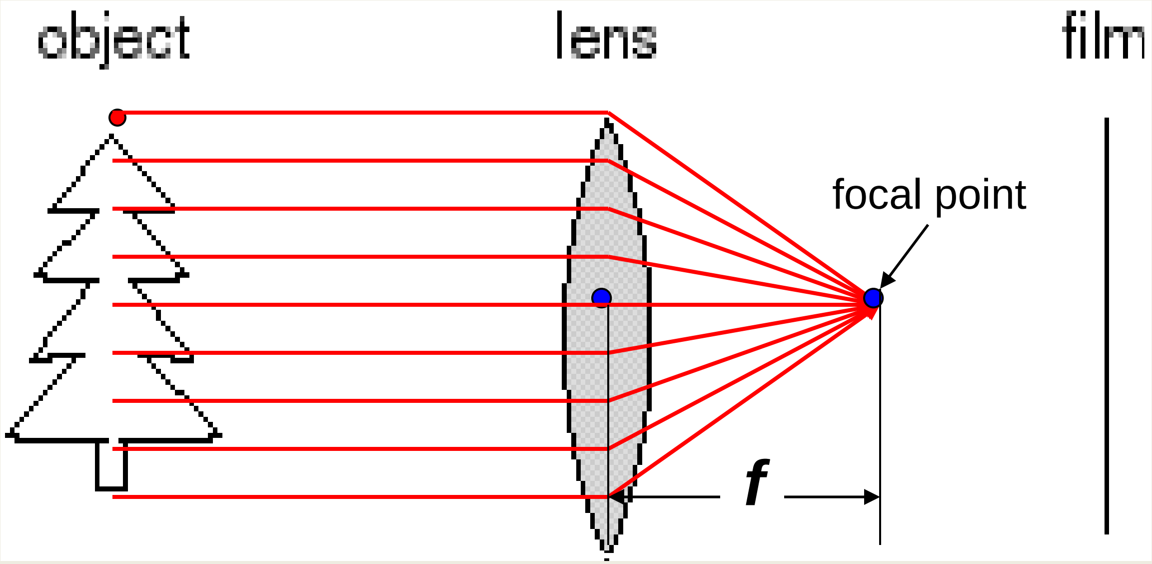


Sifat "thin" lens (Lensa Ideal)



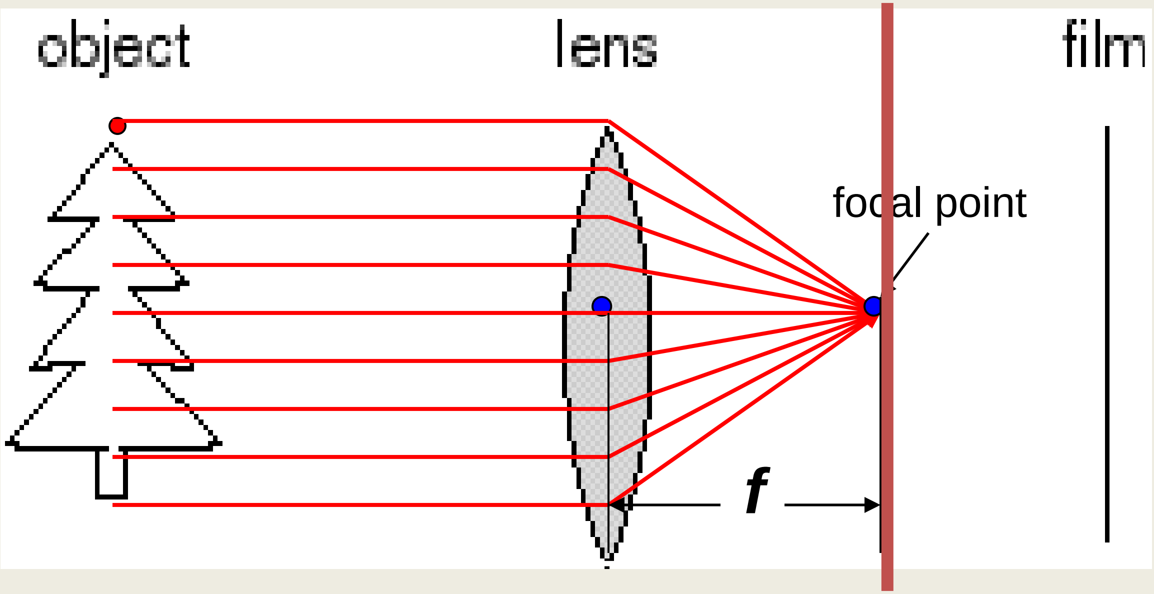
- Sinar cahaya melewati pusat tidak menyimpang.
- Sinar cahaya melewati titik yang jauh dari pusat menyimpang lebih banyak..

Sifat "thin" lens
(Lensa Ideal)



- Semua sinar paralel konvergen ke satu titik.
- Ketika sinar tegak lurus terhadap lensa, hal itu disebut titik fokus.

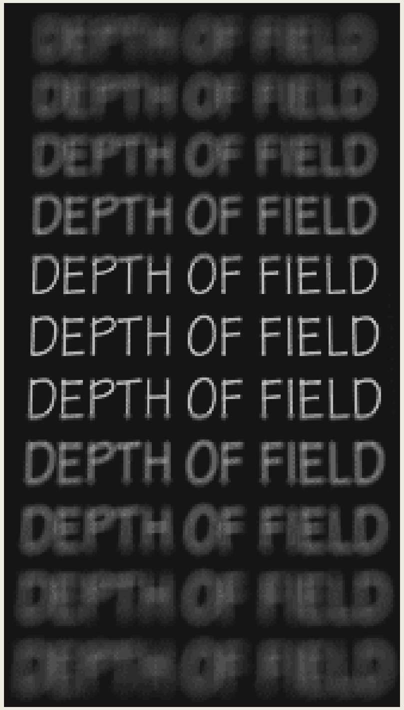
Properties of “thin” lens



- Bidang sejajar dengan lensa pada titik fokus disebut bidang fokus. (focal plane).
- Jarak antara lensa dan bidang fokus disebut panjang fokus (yaitu, f =focal length)lensa.

Depth of Field

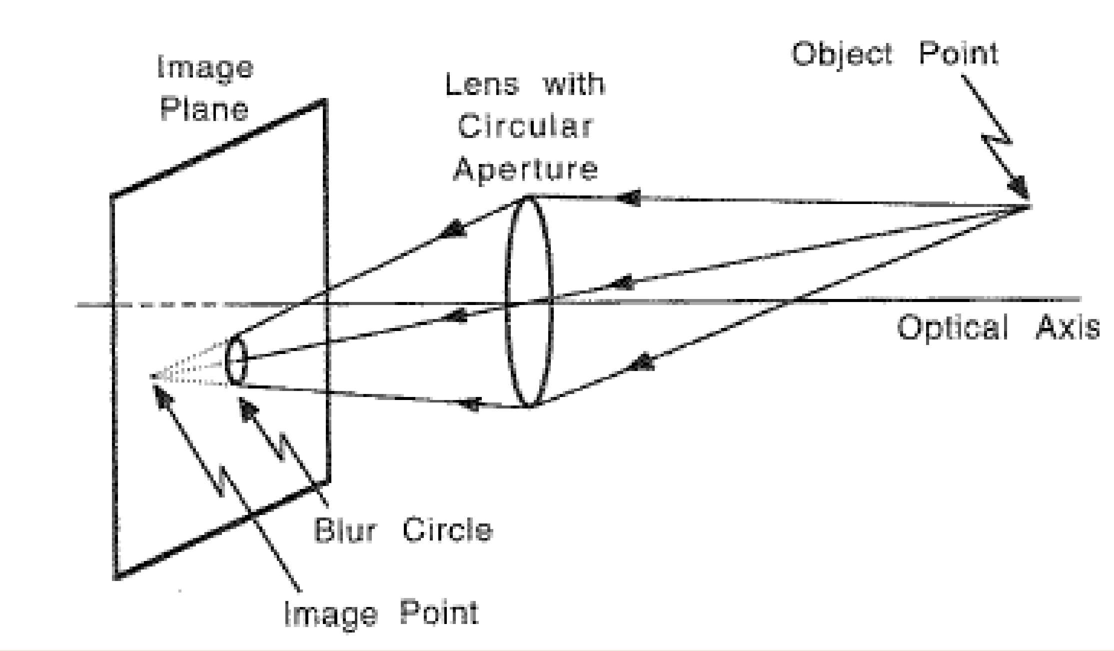
Ukuran seberapa jauh bidang fokus/ ketajaman dalam gambar.



http://www.cambridgeincolour.com/tutorials/depth-of-field.htm

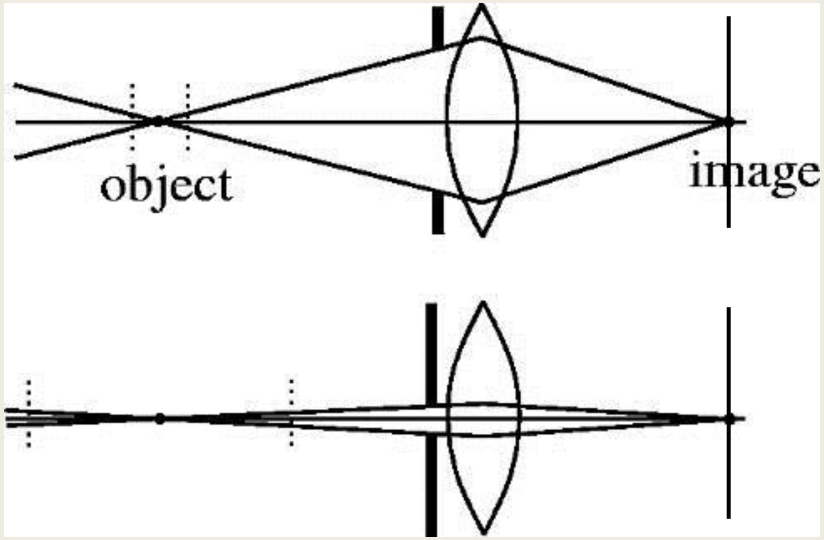
Bagaimana kita bisa mengontrol *Depth of Field*?

- Ukuran lingkaran blur sebanding dengan ukuran *aperture*.



Bagaimana kita bisa mengontrol *Depth of Field*? (lanjutan)

- Mengubah ukuran *aperture* (dikontrol oleh diagfragma) mempengaruhi *depth of field*.
  - *Aperture* yang lebih kecil meningkatkan rentang di mana objek di sekitar fokus (tetapi perlu meningkatkan exposure time).
  - *Aperture* yang lebih besar mengurangi DOF (tetapi perlu mengurangi exposure time)



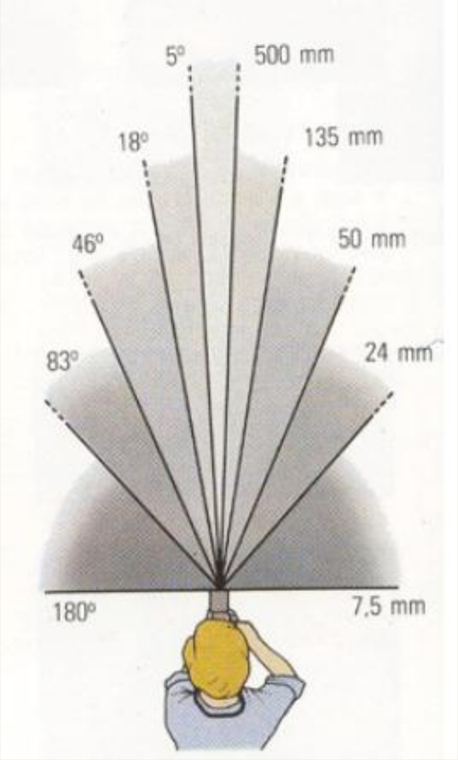
Berbagai Ukuran *Aperture*

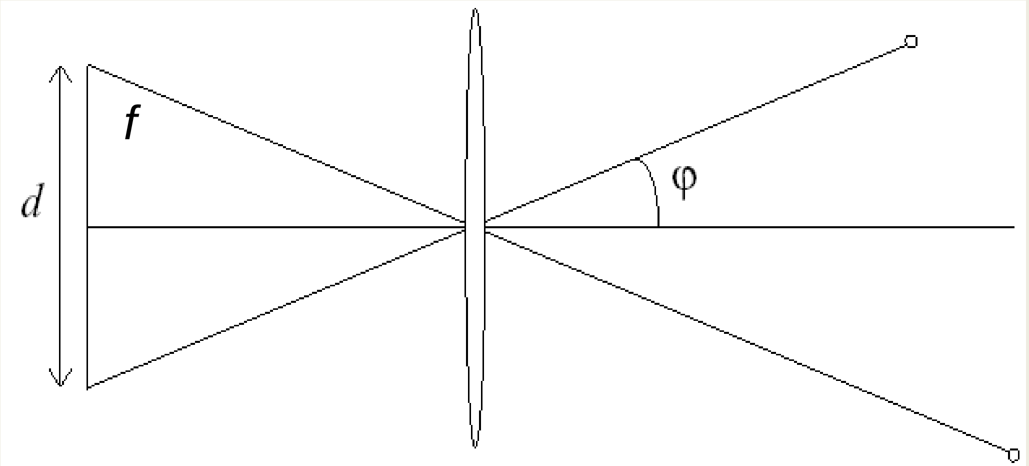
Aperture Besar = DOF Kecil

Aperture Kecil = DOF Besar

Bidang Pandang (Zoom)

- Kerucut arah pandang kamera.
- Berbanding terbalik dengan panjang fokus.

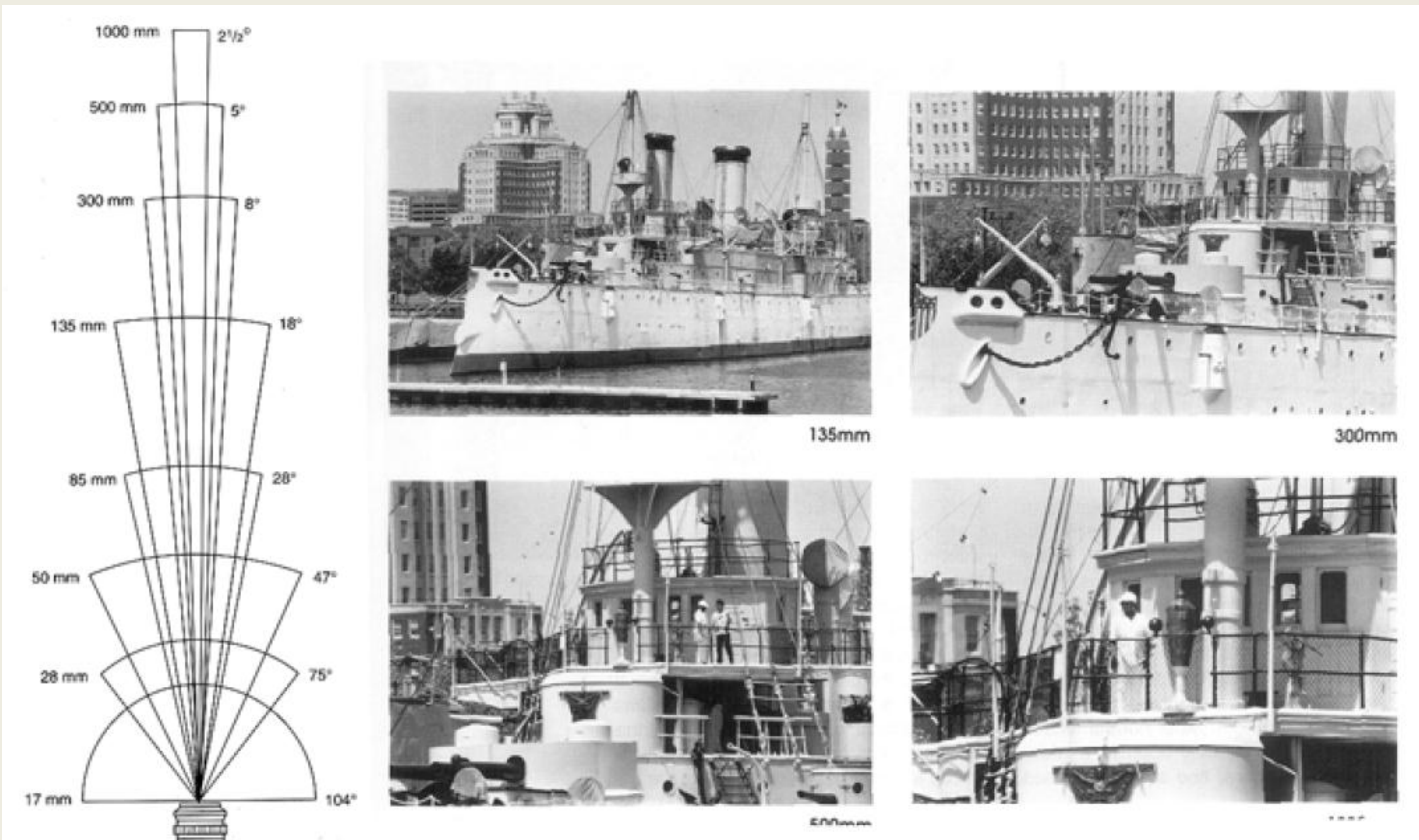




Size of field of view governed by size of the camera retina:

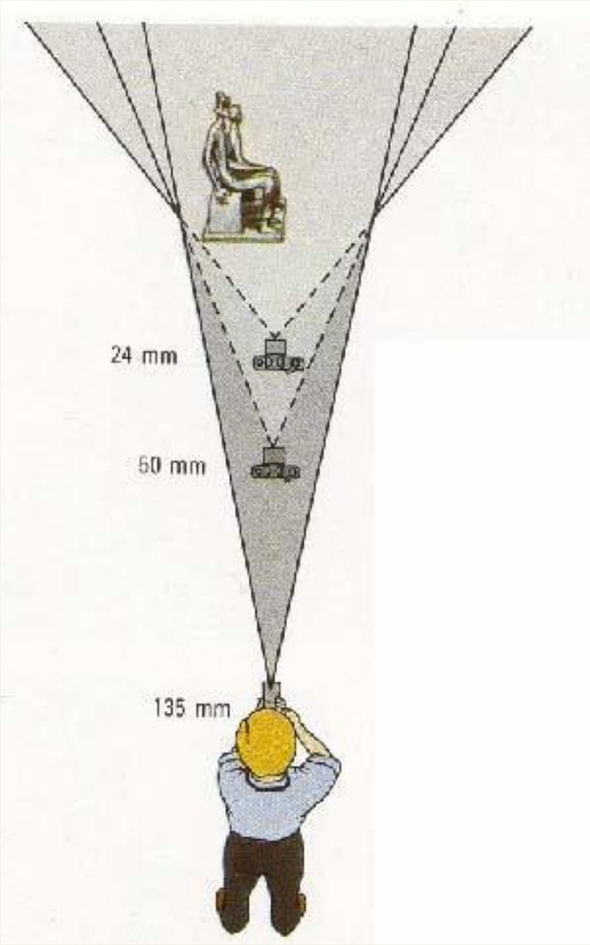
$$\varphi = \tan^{-1}\left(\frac{d}{2f}\right)$$

Bidang Pandang (Zoom)



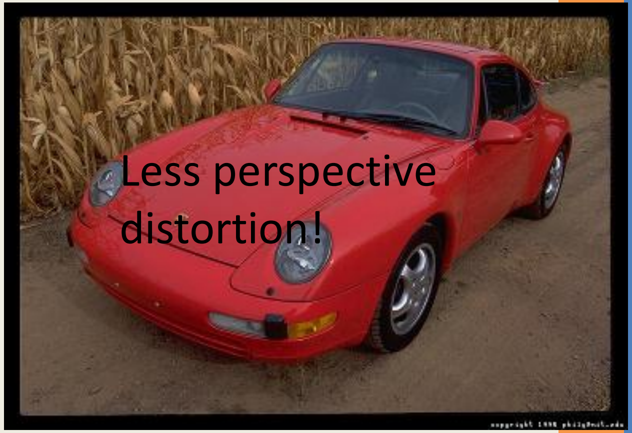
From London and Upton

Mengurangi Distorsi Perspective dengan Memvariasikan Jarak / Focal Length



Small f (i.e., large FOV), camera close to car

Large f (i.e., small FOV), camera far from car



Efek Yang Sama Pada Wajah

wide-angle

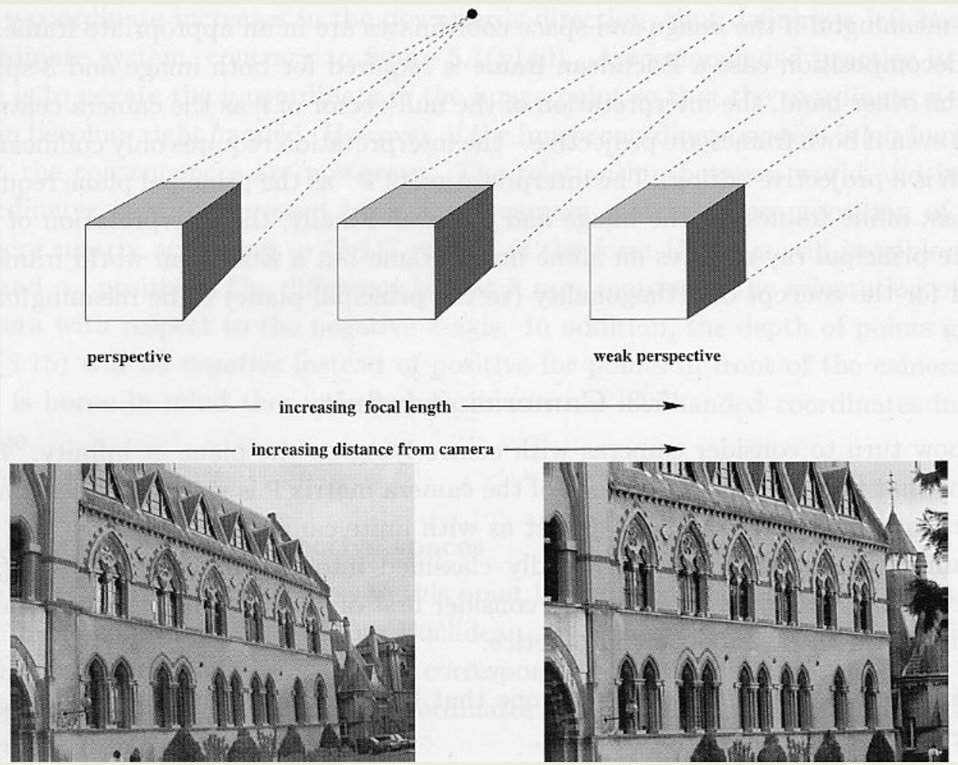
standard

telephoto

<u>Penting</u>:
Kita dapat mendekati proyeksi perspektif
menggunakan model sederhana bila menggunakan lensa tele untuk melihat jauh objek yang memiliki kisaran DOF yang kecil.

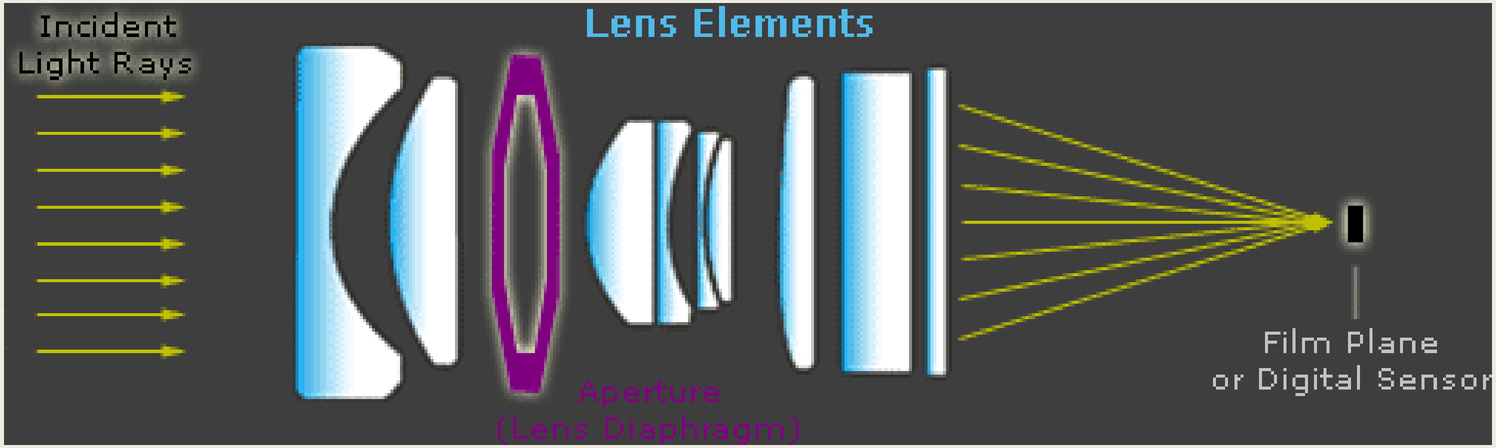
Pendekatan kamera “affine”

Pusat proyeksi berada di tak hingga !



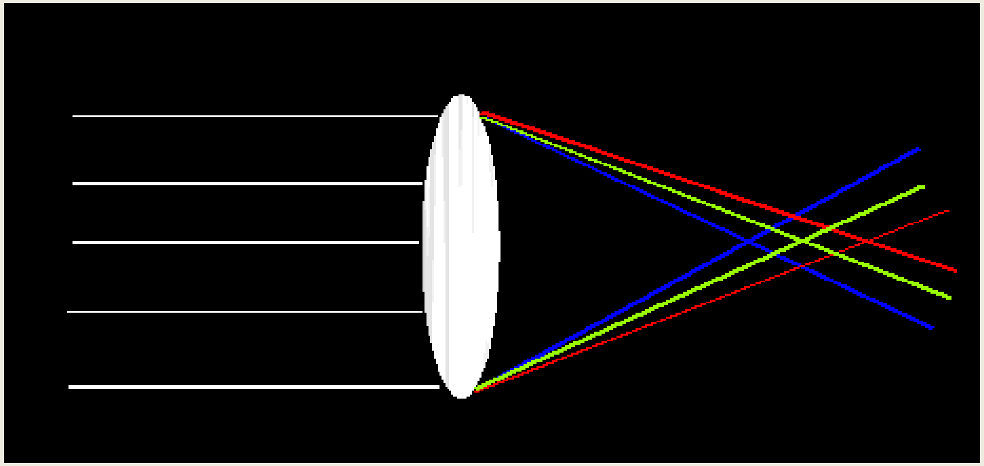
Lensa Nyata

- All but the simplest cameras contain lenses which are actually comprised of several "lens elements."
- Each element aims to direct the path of light rays such that they recreate the image as accurately as possible on the digital sensor.



Hukum Lensa : Chromatic Aberration

- Lensa memiliki indeks bias yang berbeda untuk panjang gelombang yang berbeda
- Dapat menyebabkan warna fringing (biasanya terlihat pada tepi kontras tinggi dalam gambar) :
  - misalkan lensa tidak dapat fokus pada semua warna pada satu titik yang sama

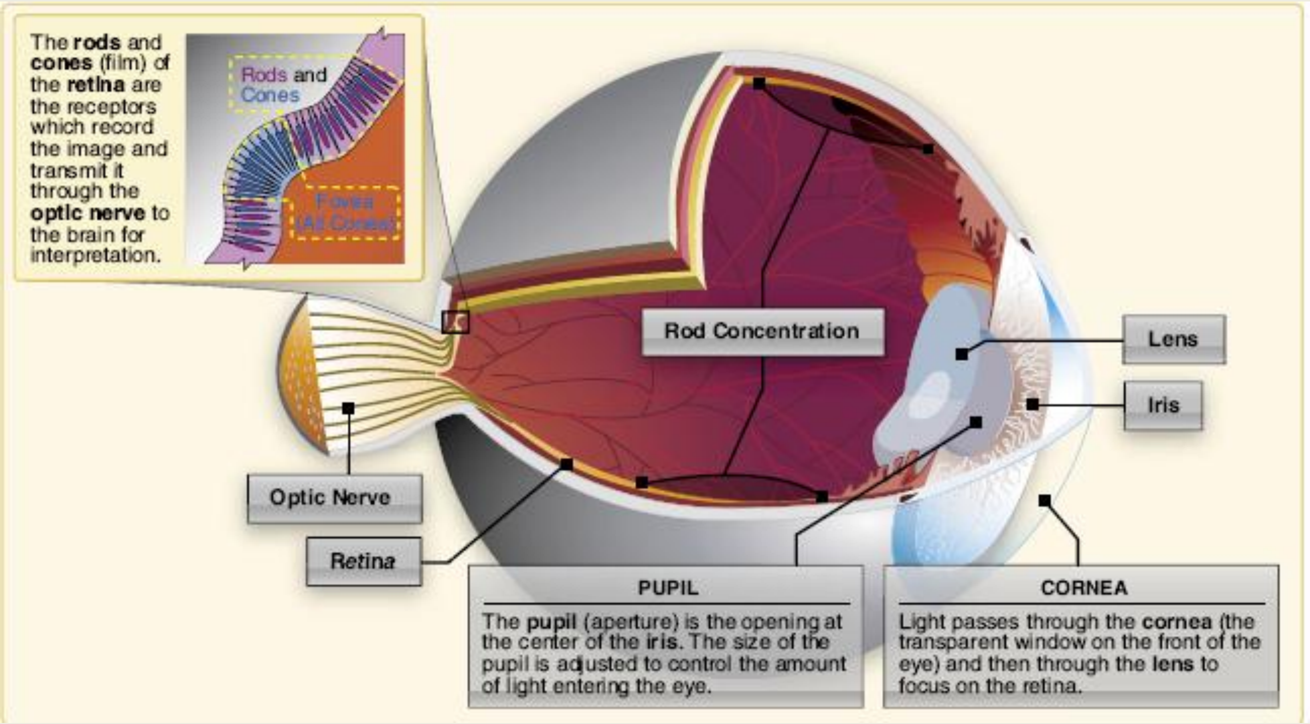


Contoh : Chromatic Aberration

Human Eye

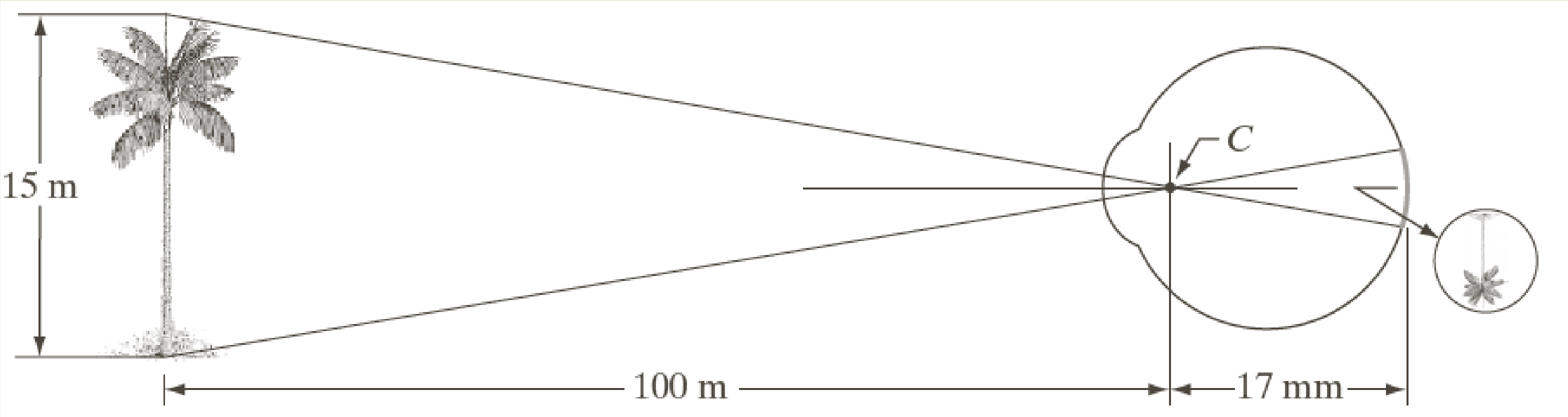
- Fungsinya menyerupai kamera :

aperture (adalah:pupil), lens, mekanisme untuk fokus (zoom in/out) dan permukaan untuk mendaftarkan gambar (adalah:retina)



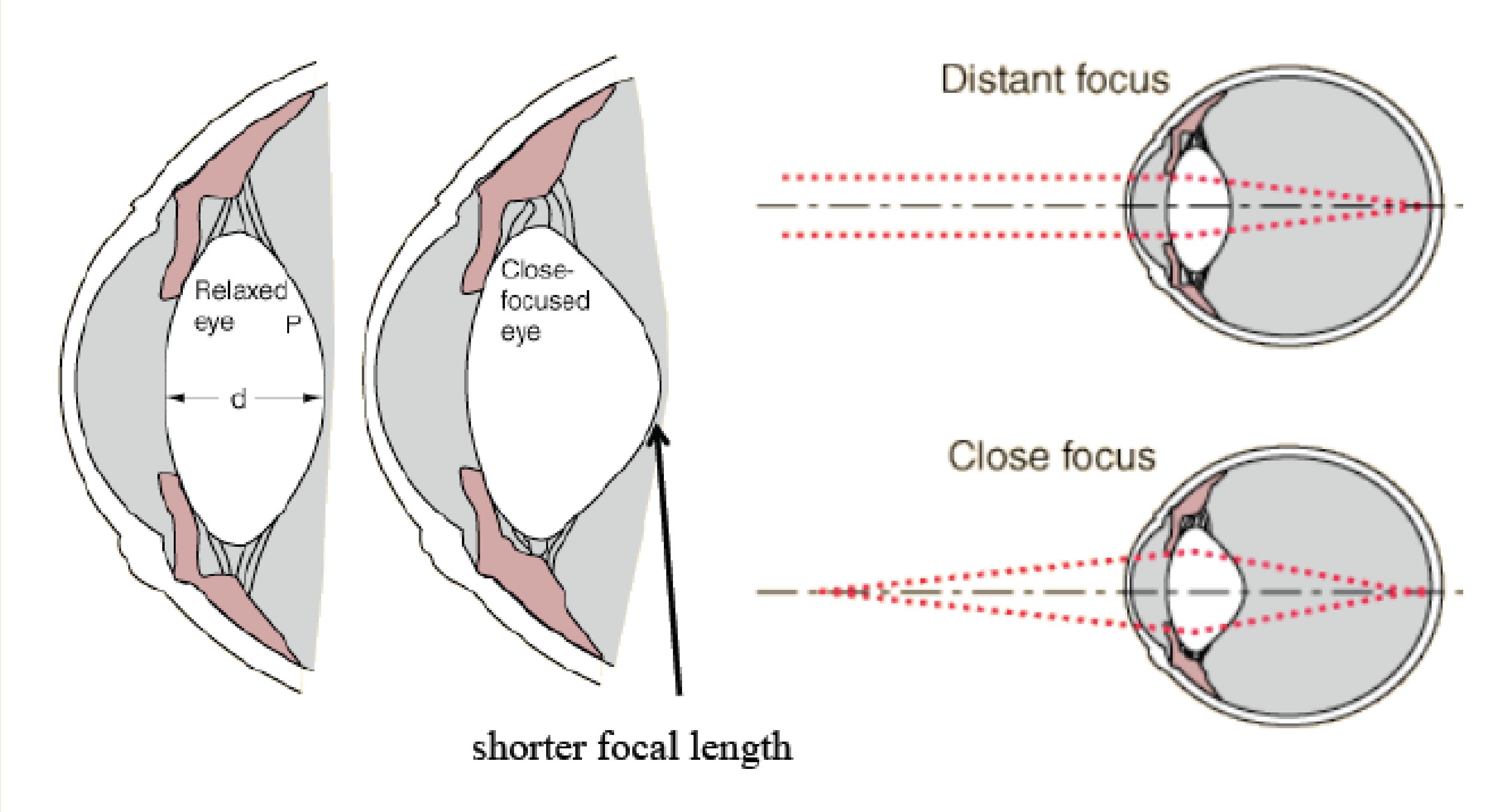
Human Eye (lanjutan)

- Pada kamera, fokus pada bermacam jarak dicapai dengan bermacam-macam jarak diantara lensa dan bidang gambar
- Pada human eye, jarak diantara lensa dan retina tetap (misal: 14mm sampai 17mm).



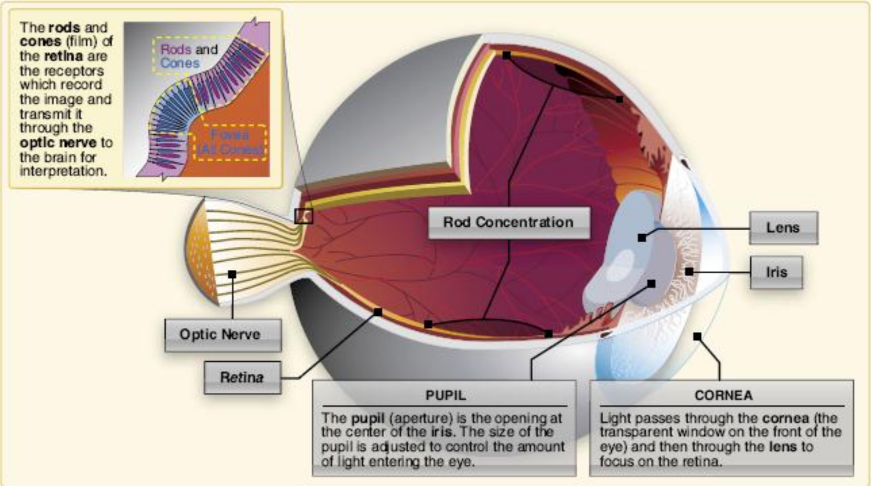
Human Eye (lanjutan)

- Fokus dicapai dengan bermacam-macam bentuk lensa (misal: merata penebalan).



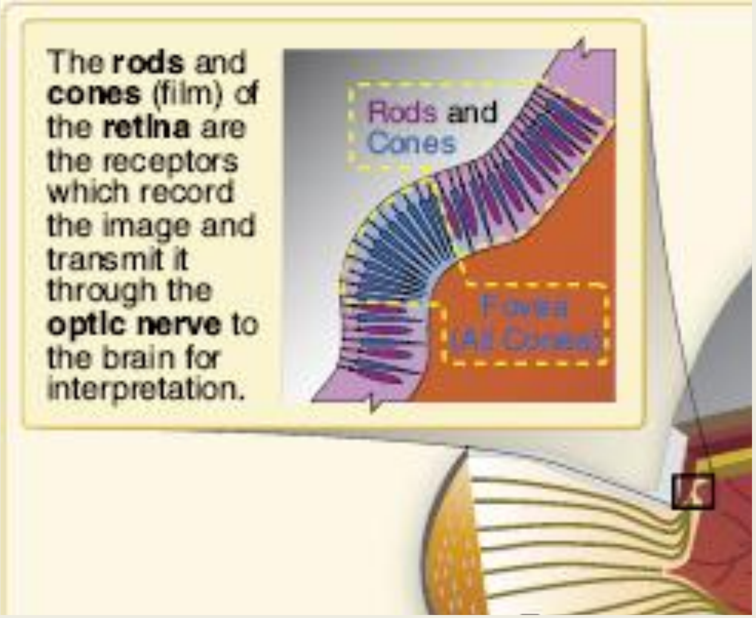
Human Eye (lanjutan)

- Retina contains light sensitive cells that convert light energy into electrical impulses that travel through nerves to the brain.
- Brain interprets the electrical signals to form images.



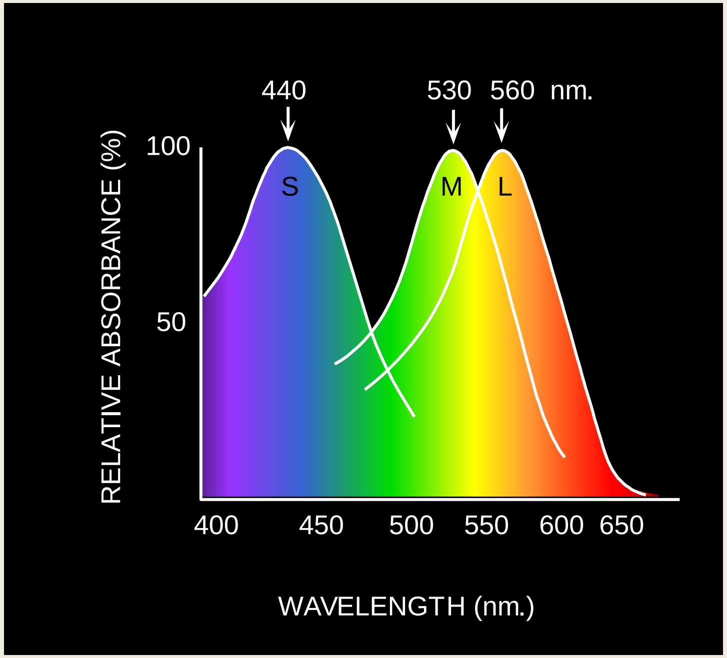
Human Eye (Lanjutan)

- Two kinds of light-sensitive cells: rods and cone (unevenly distributed).
- Cones (6 – 7 million) are responsible for all color vision and are present throughout the retina, but are concentrated toward the center of the field of vision at the back of the retina.
- Fovea – special area
  - Mostly cones.
  - Detail, color sensitivity, and resolution are highest.



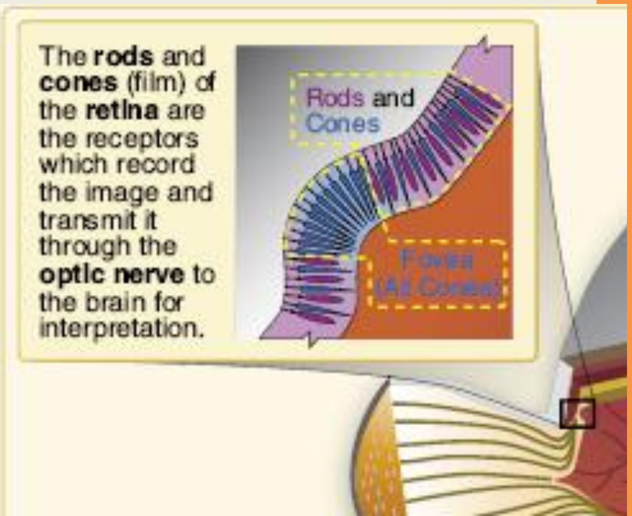
Human Eye(lanjutan)

- Three different types of cones; each type has a special pigment that is sensitive to wavelengths of light in a certain range:
  - Short (S) corresponds to blue
  - Medium (M) corresponds to green
  - Long (L) corresponds to red
- Ratio of L to M to S cones:
  - approx. 10:5:1
- Almost no S cones in the center of the fovea

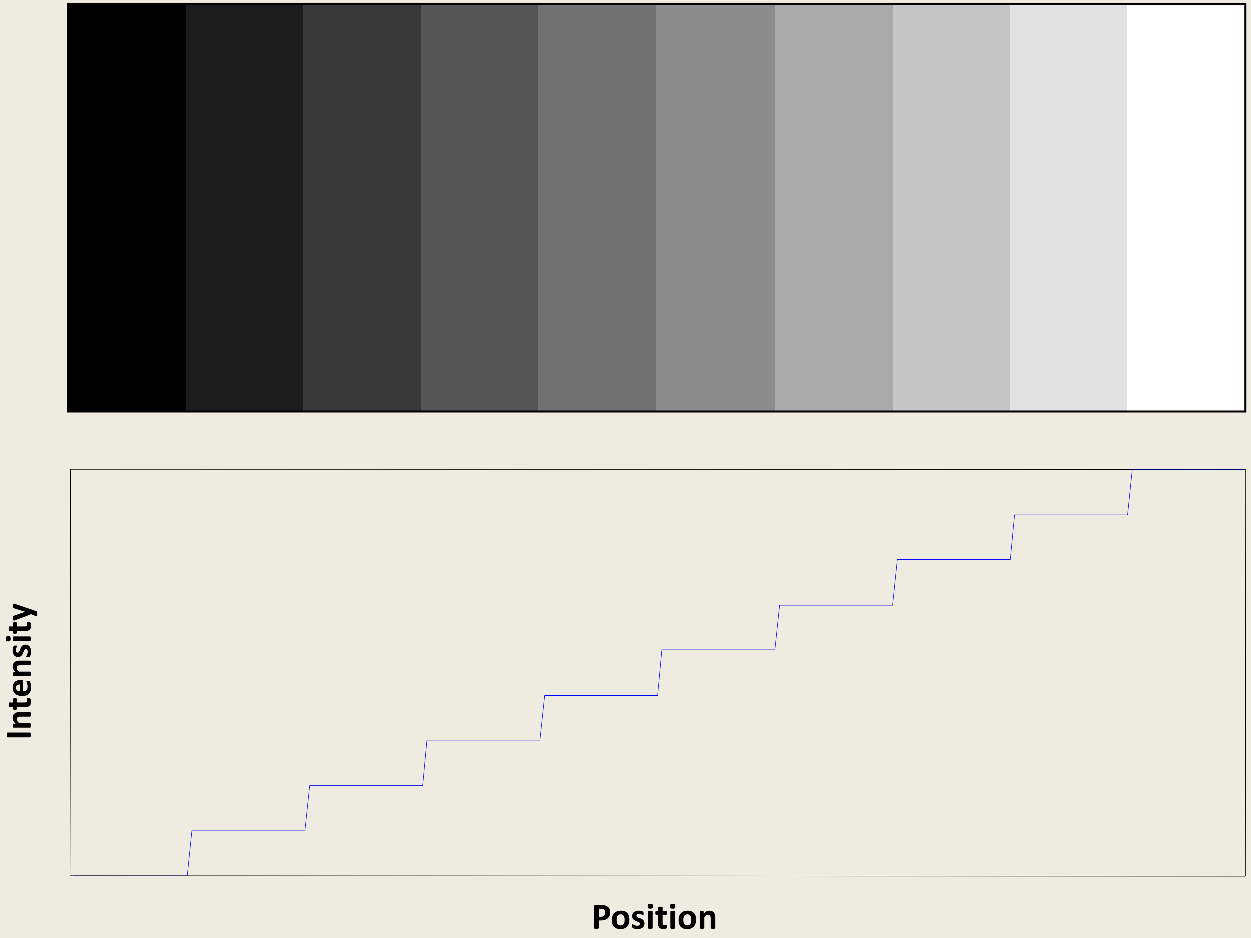


Human Eye (lanjutan)

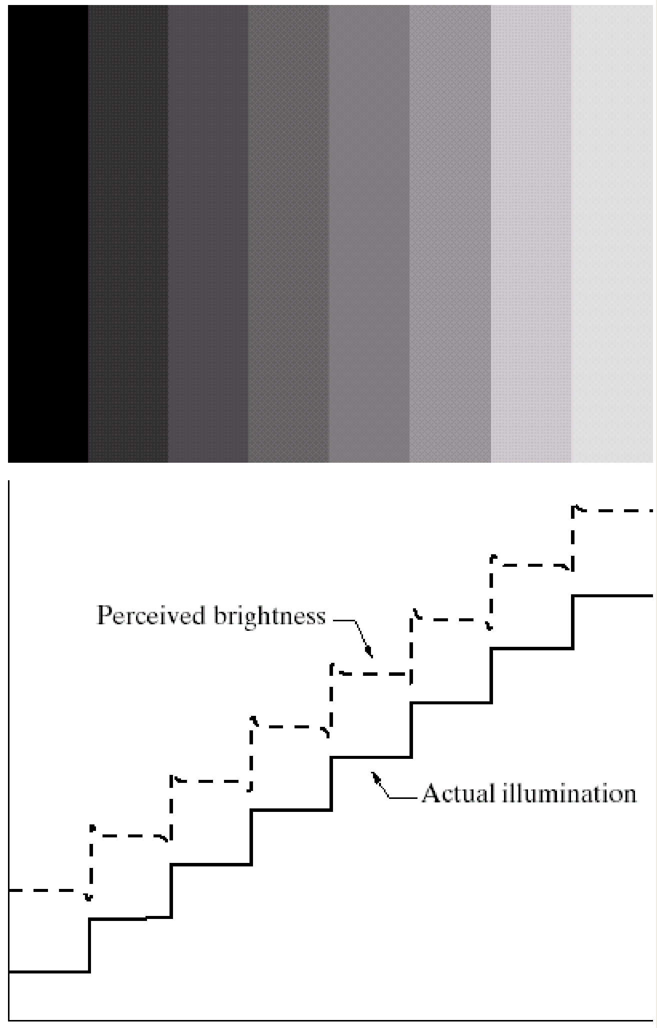
- Rods (120 million) more sensitive to light than cones but cannot discern color.
  - Primary receptors for night vision and detecting motion.
  - Large amount of light overwhelms them, and they take a long time to “reset” and adapt to the dark again.
  - Once fully adapted to darkness, the rods are 10,000 times more sensitive to light than the cones



Brightness Adaptation of Human Eye : Mach Band Effect



Mach Band Effect

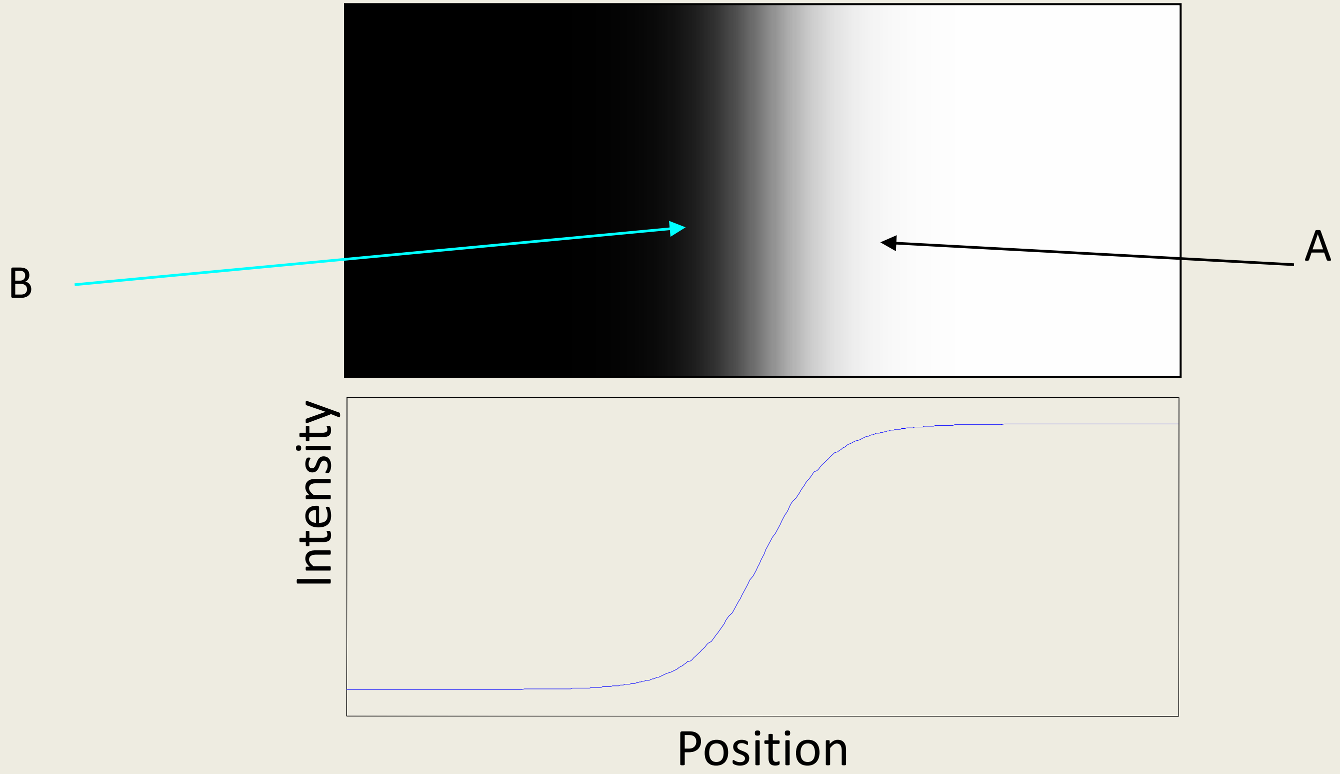


Intensities of surrounding points effect perceived brightness at each point.

In this image, edges between bars appear brighter on the right side and darker on the left side.

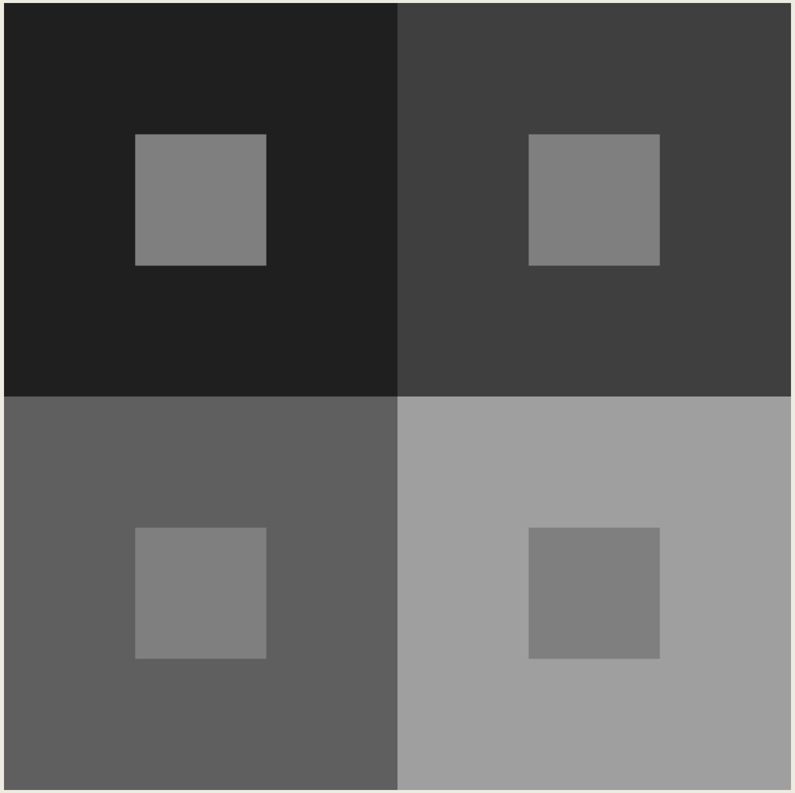
(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Mach Band Effect (Cont)



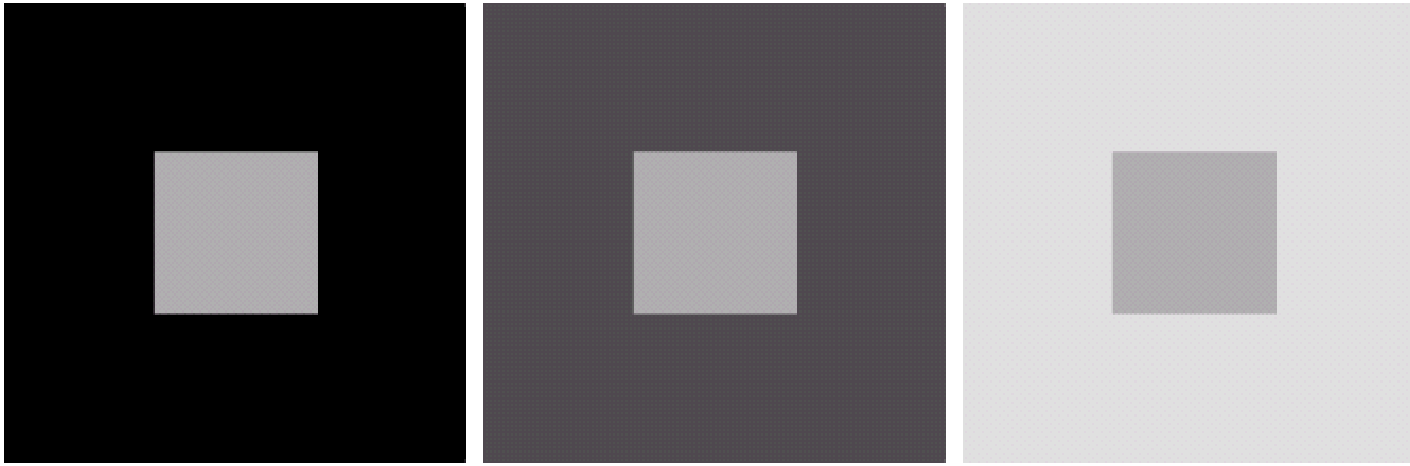
In area A, brightness perceived is darker while in area B is brighter. This phenomenon is called ***Mach Band Effect***.

Brightness Adaptation of Human Eye : Simultaneous Contrast



Simultaneous contrast. All small squares have exactly the same intensity but they appear progressively darker as background becomes lighter.

Simultaneous Contrast

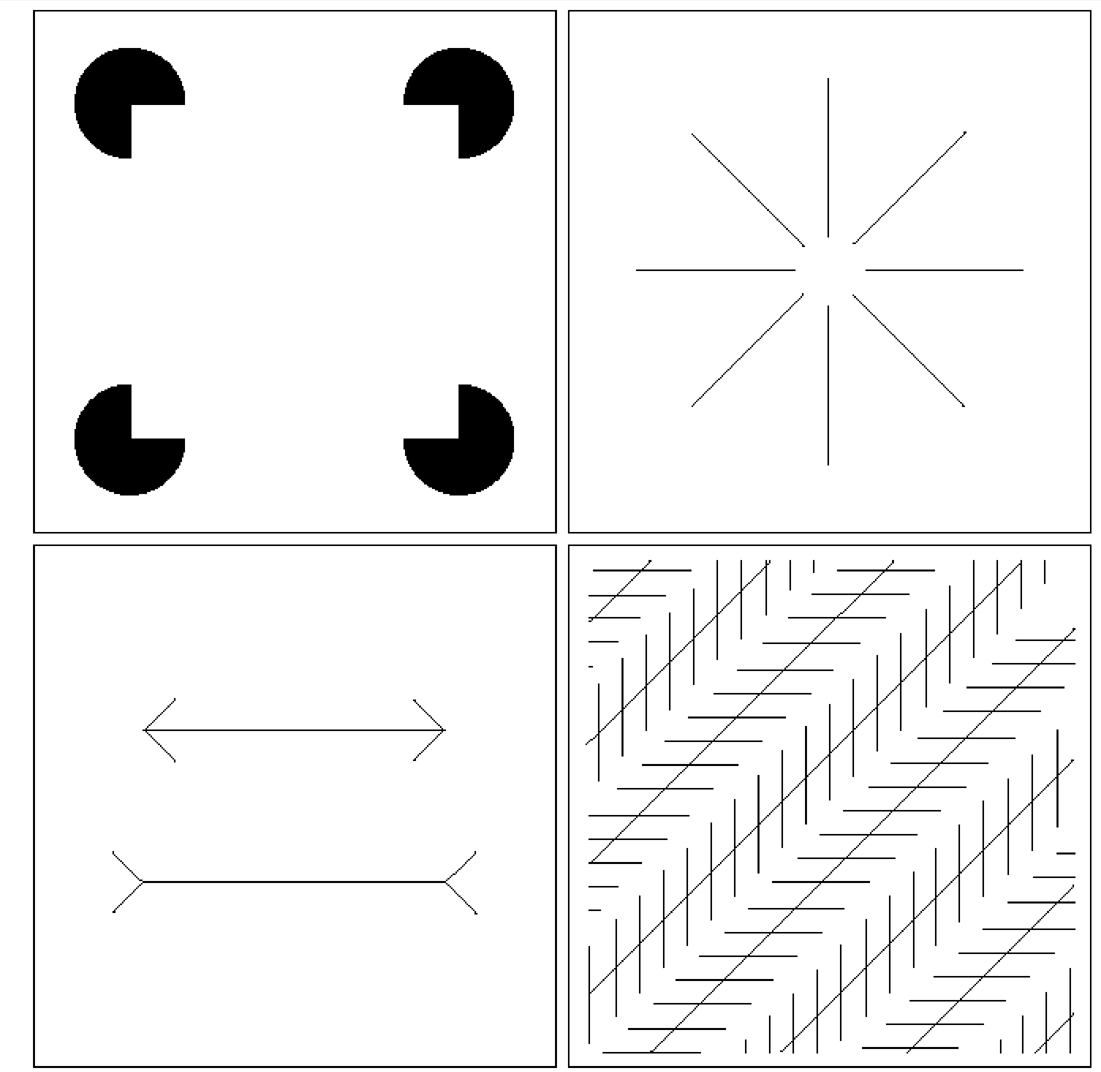


a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Optical illusion



(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Visible Spectrum

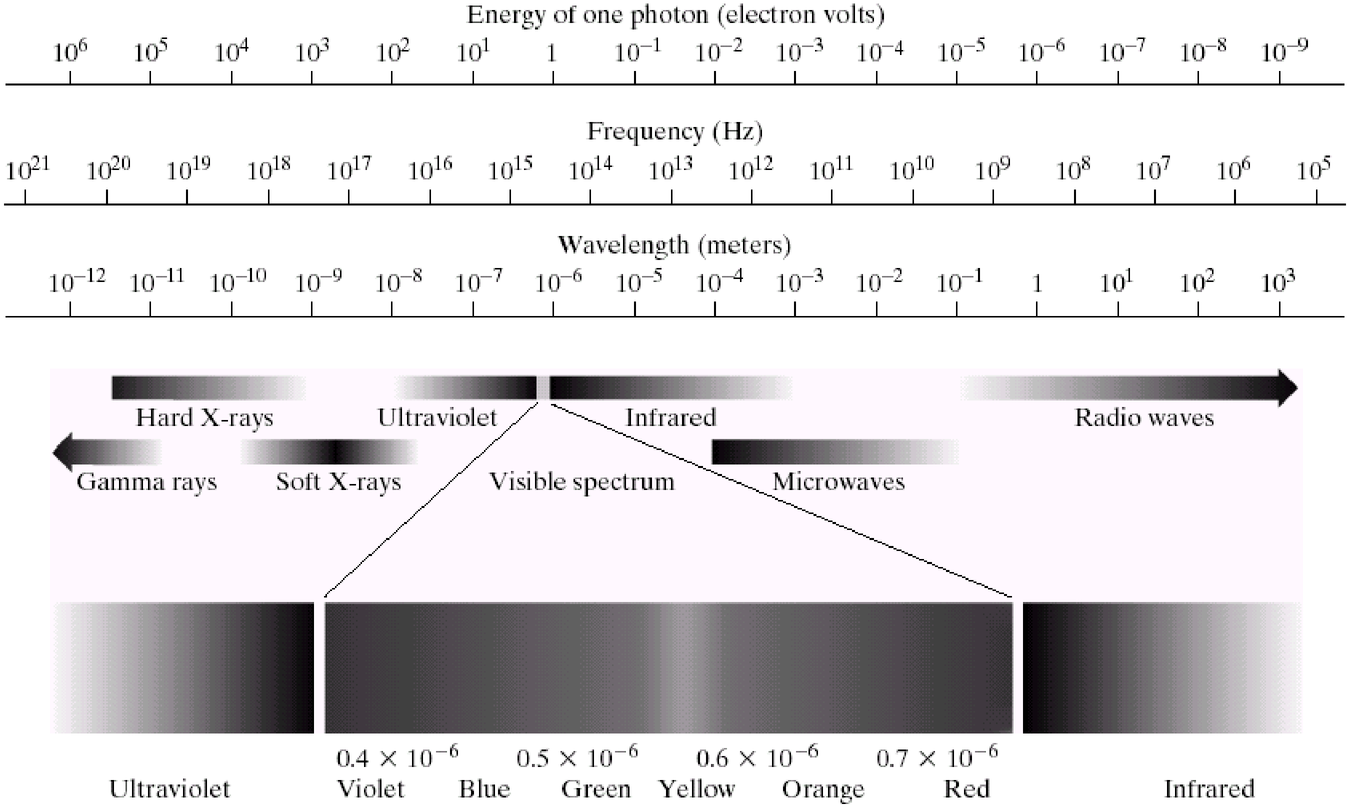
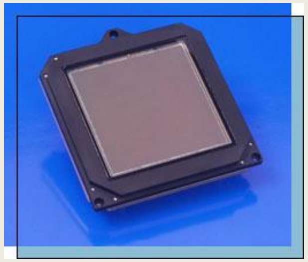


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

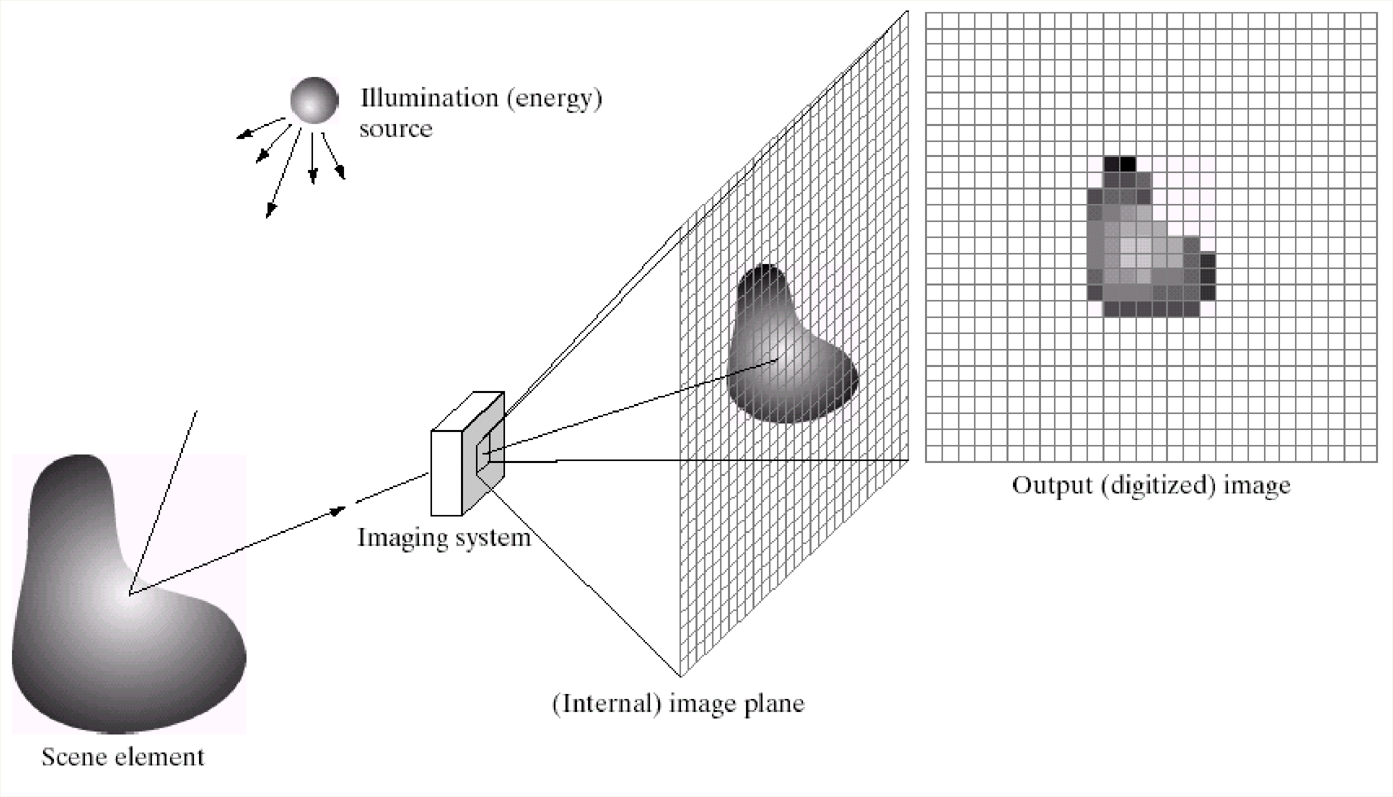
Digital cameras

- A digital camera replaces film with a sensor array.
  - Each cell in the array is light-sensitive diode that converts photons to electrons
  - Two common types
    - Charge Coupled Device (CCD)
    - Complementary metal oxide semiconductor (CMOS)

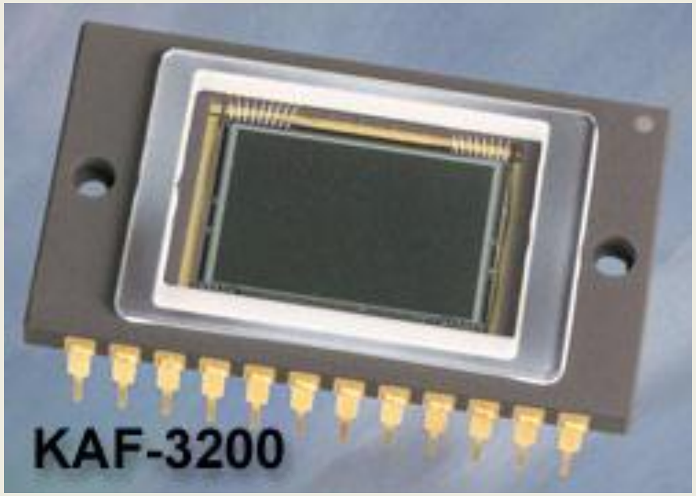


http://electronics.howstuffworks.com/digital-camera.htm

Digital cameras (cont'd)



Charge-Coupled Device (CCD)

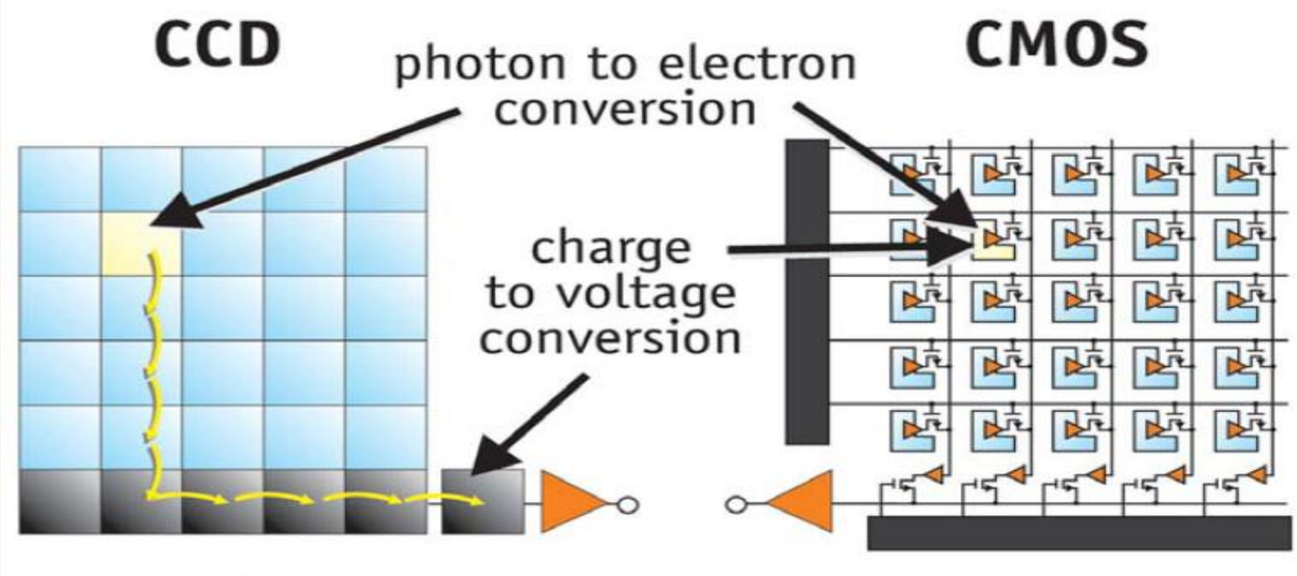


CCD KAF-3200E from Kodak.
(2184 x 1472 pixels,
Pixel size 6.8 microns^2)

- Used for convert a continuous image into a digital image
- Contains an array of light sensors
- Converts photon into electric charges accumulated in each sensor unit

CCD Cameras

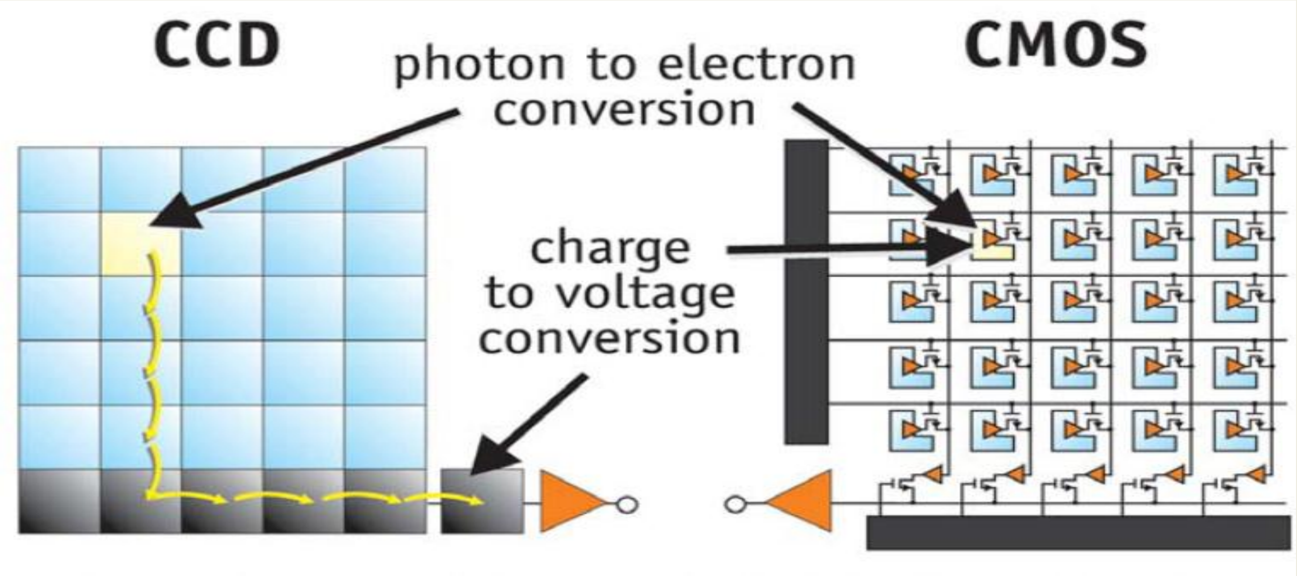
- CCDs move photogenerated charge from pixel to pixel and convert it to voltage at an output node.
- An **analog-to-digital converter (ADC)** then turns each pixel's value into a digital value.



http://www.dalsa.com/shared/content/pdfs/CCD_vs_CMOS_Litwiller_2005.pdf

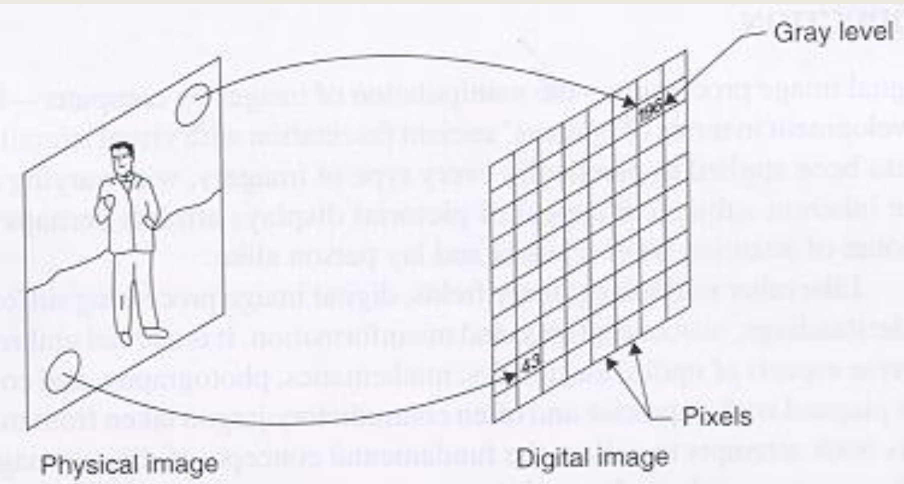
CMOS Cameras

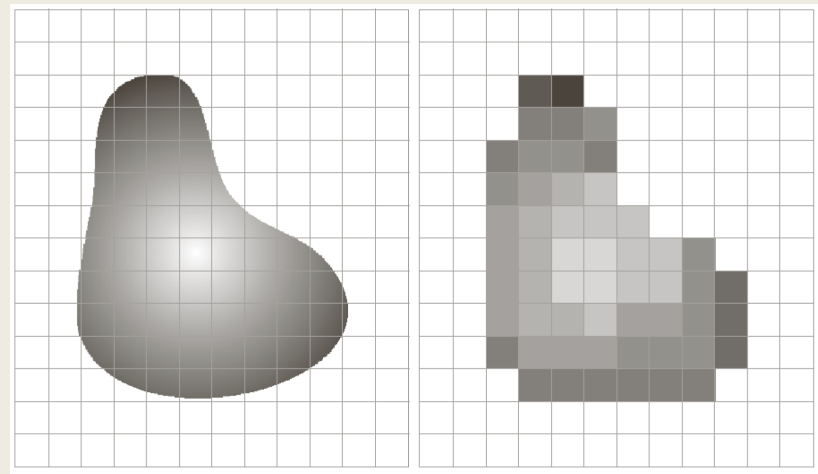
- CMOs convert charge to voltage inside each element.
- Uses several transistors at each pixel to amplify and move the charge using more traditional wires.
- The CMOS signal is digital, so it needs no ADC.



http://www.dalsa.com/shared/content/pdfs/CCD_vs_CMOS_Litwiller_2005.pdf

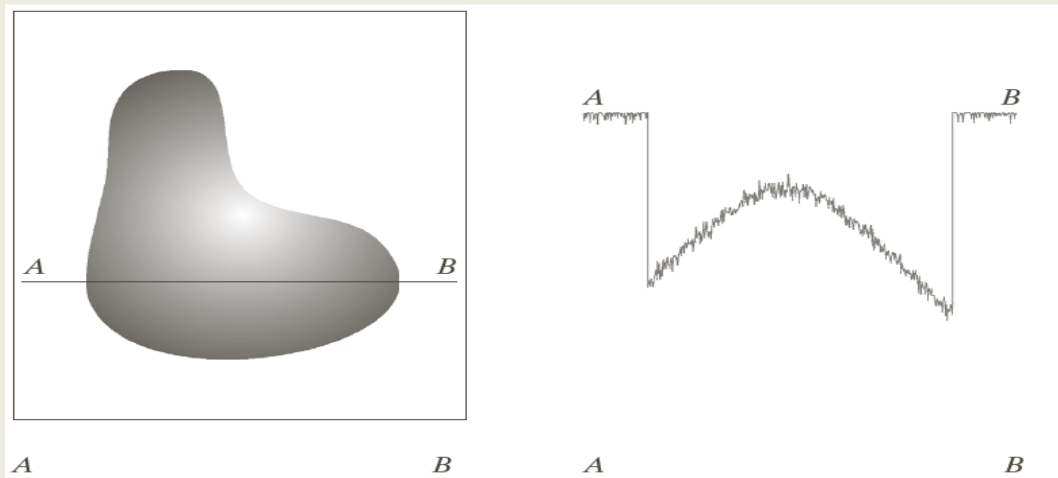
Image digitization





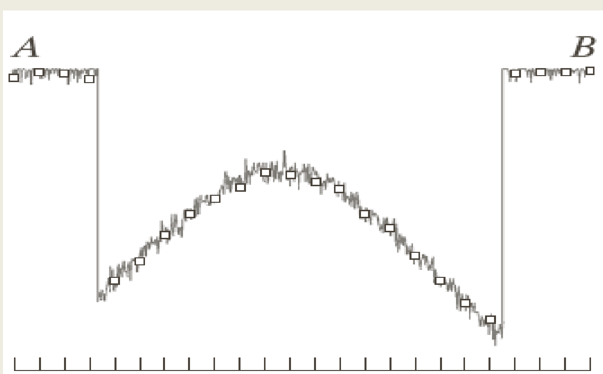
- **Sampling**: measure the value of an image at a finite number of points.
- **Quantization**: represent measured value (i.e., voltage) at the sampled point by an integer.

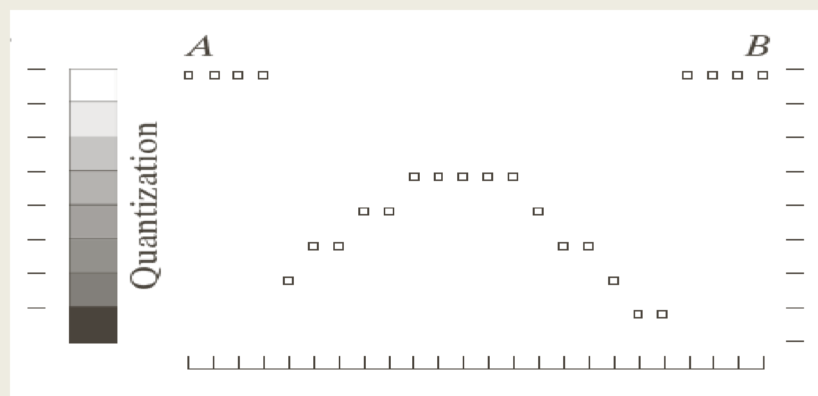
Image digitization (cont'd)



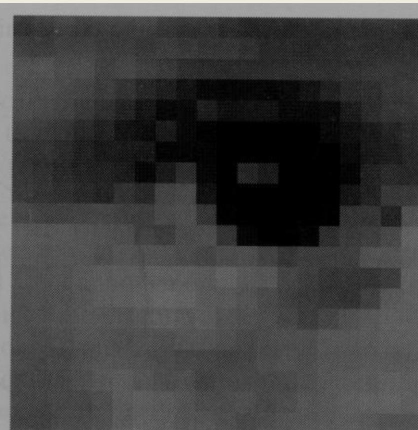
Sampling

Quantization



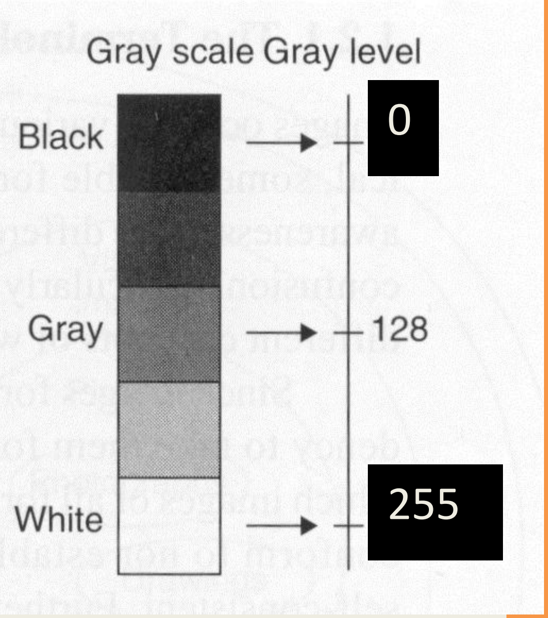


What is an image?



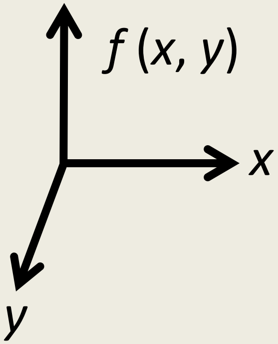
117	125	133	127	130	130	133	121	116	115	100	91	93	94	99	103	112	105	109	106
134	133	138	138	132	134	130	133	128	123	121	113	106	102	99	106	113	109	109	113
146	147	138	140	125	134	124	115	102	96	93	94	99	96	99	100	103	110	109	110
144	141	136	130	120	108	88	74	53	37	31	37	35	39	53	79	93	100	109	116
139	136	129	119	102	85	58	31	41	77	51	53	53	33	37	41	69	94	105	108
132	127	117	102	87	57	49	77	42	28	17	15	13	13	17	41	53	69	88	100
124	120	108	94	72	74	72	31	35	31	15	13	15	11	15	13	46	75	83	96
125	115	102	93	88	82	42	79	113	41	19	100	82	11	11	17	31	91	99	100
124	116	109	99	91	113	99	140	144	57	20	20	15	11	15	17	63	87	119	124
136	133	133	135	138	133	132	144	150	120	24	17	15	15	17	20	115	113	88	150
158	157	157	154	149	145	133	127	146	150	116	35	20	19	28	105	124	128	141	171
155	154	156	155	146	155	154	154	147	139	148	150	138	120	128	129	130	151	156	165
150	151	154	162	166	167	169	174	172	167	177	166	164	140	134	120	121	120	127	172
145	149	151	157	165	169	173	179	176	166	166	157	145	136	129	124	120	136	163	168
144	148	153	160	159	158	165	172	165	169	157	151	149	141	130	140	151	162	169	167
144	141	147	155	154	149	156	151	157	157	151	144	147	147	149	159	158	159	166	165
139	140	140	150	153	151	150	146	140	139	138	140	145	151	149	156	156	162	162	161
136	134	138	146	156	164	153	146	145	136	139	139	140	141	149	157	159	161	169	166
136	133	136	135	144	159	168	159	151	142	141	145	139	146	153	156	164	167	172	168
133	129	140	142	146	159	167	165	154	151	146	141	147	154	156	160	161	157	153	154

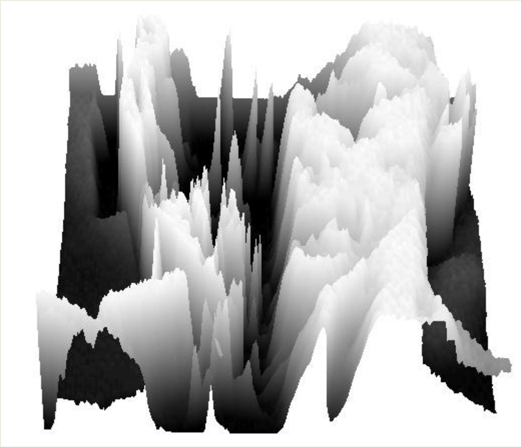
8 bits/pixel



What is an image? (cont'd)

- We can think of a (grayscale) image as a **function**, *f*, from R^2 to R (or a 2D *signal*):
  - *f* (*x*,*y*) gives the **intensity** at position (*x*,*y*)





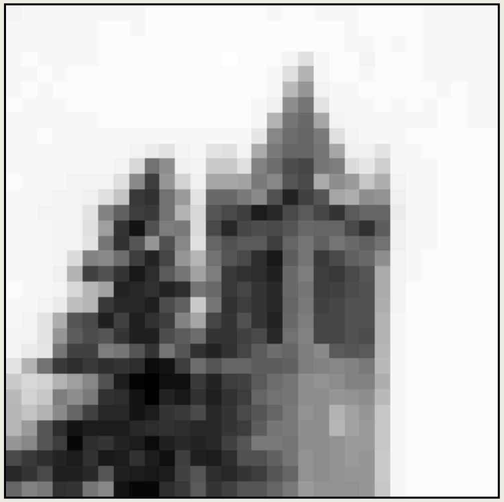
  - A **digital** image is a discrete (**sampled**, **quantized**) version of this function

Effect of Spatial Resolution

256x256 pixels

128x128 pixels

64x64 pixels



32x32 pixels

Effect of Spatial Resolution

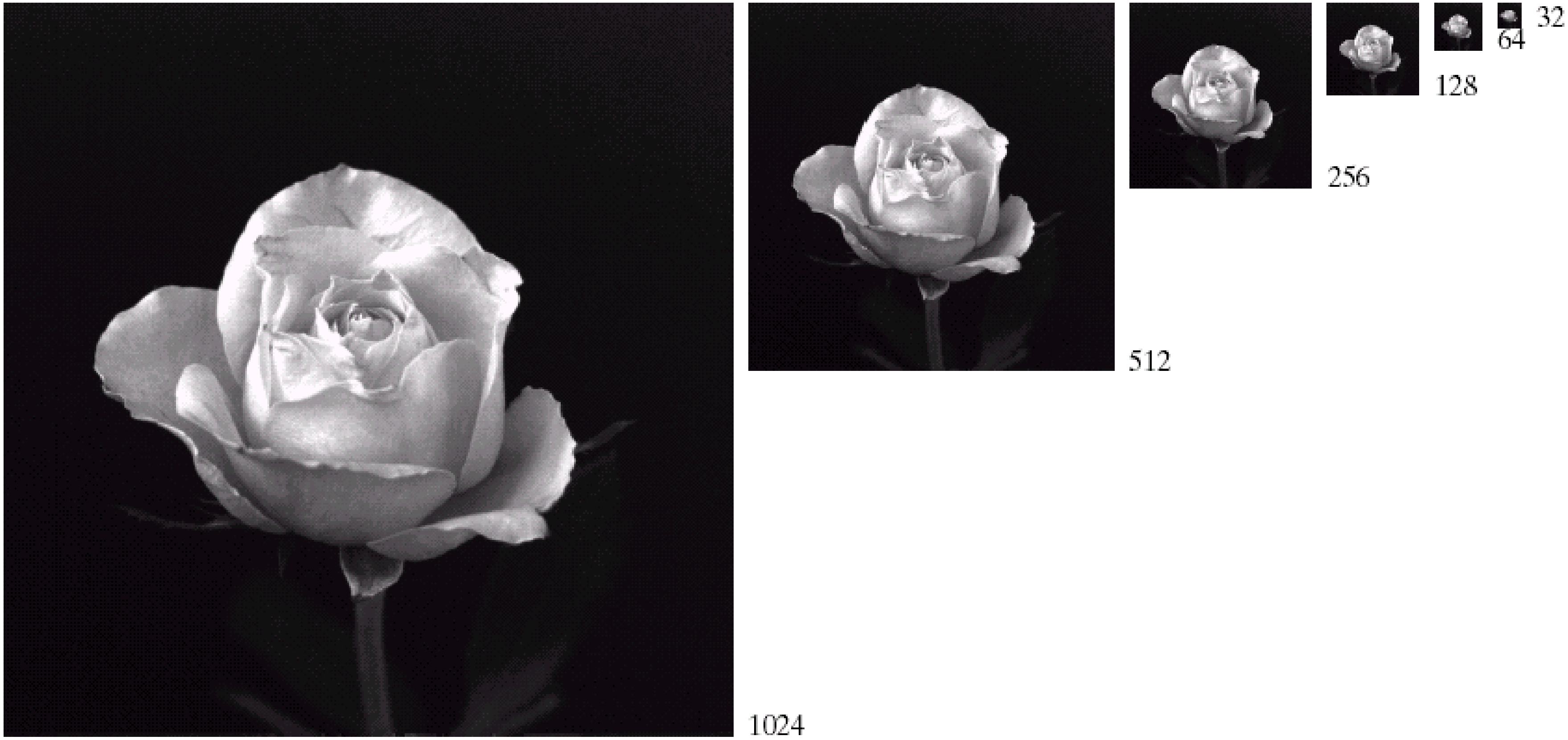
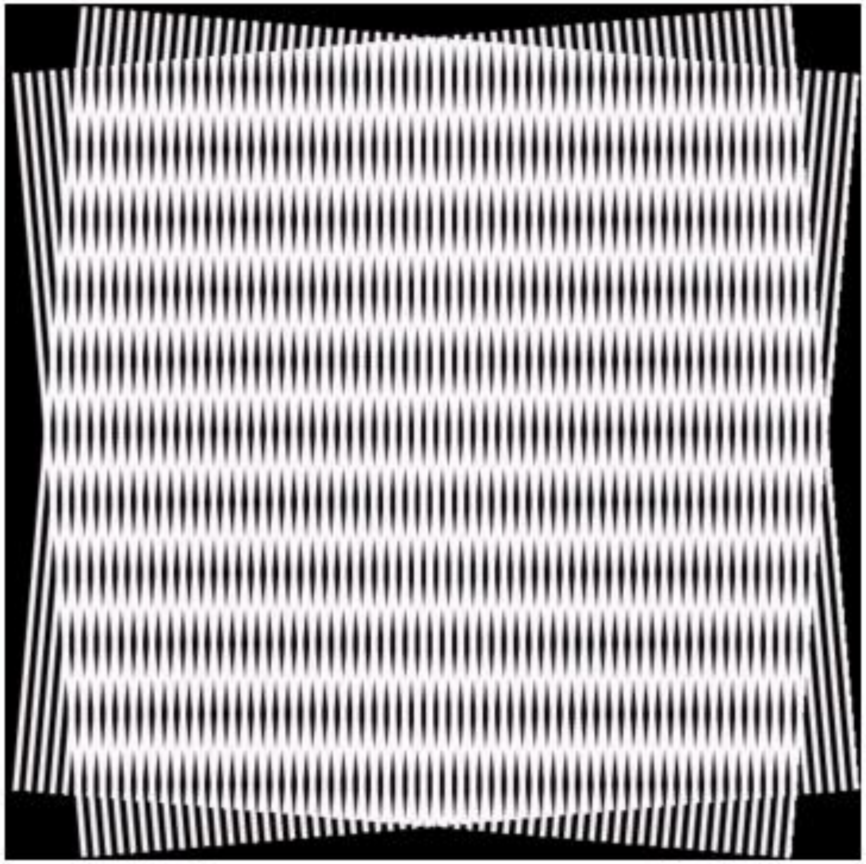


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

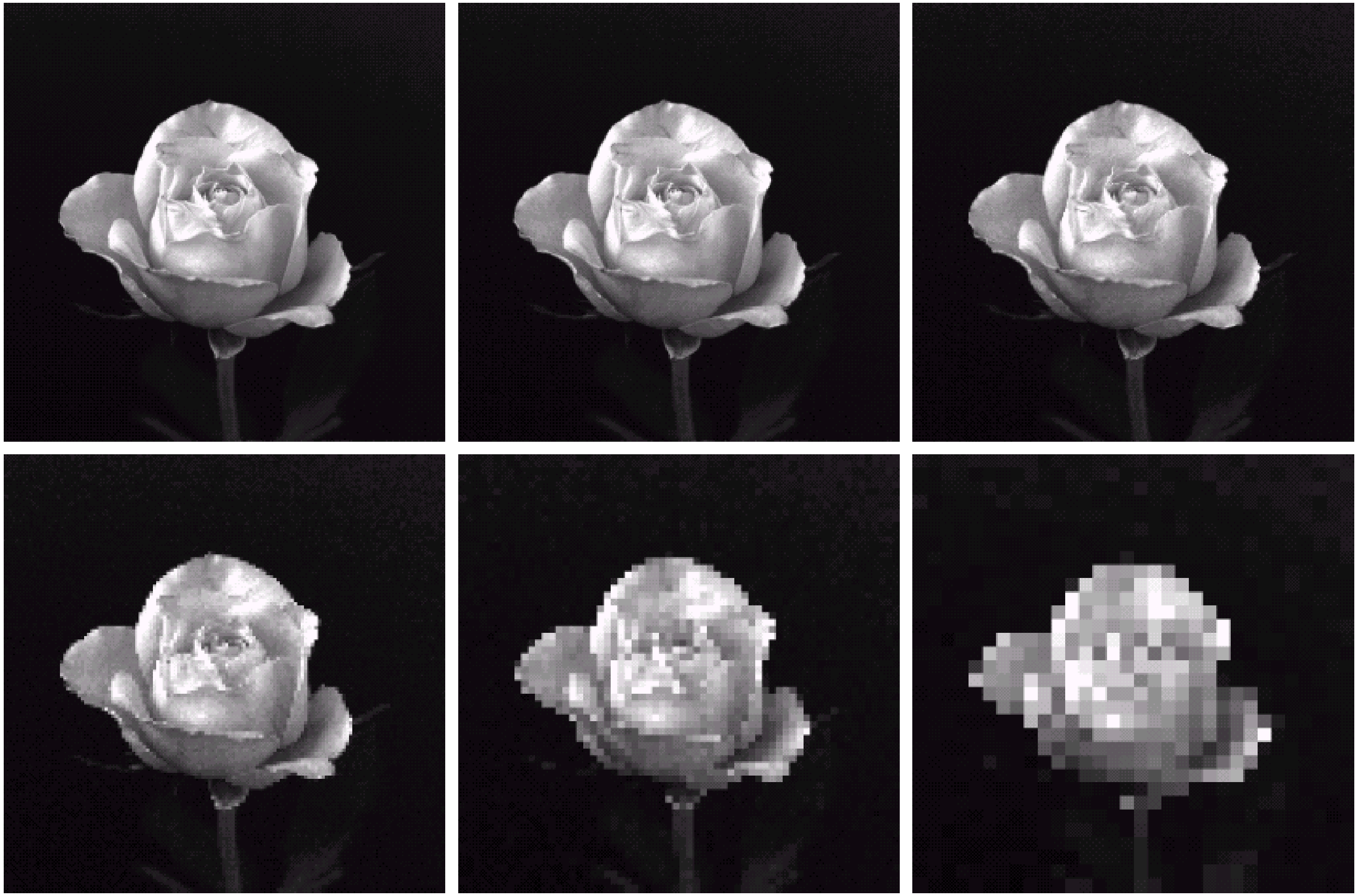
Moire Pattern Effect : Special Case of Sampling



Moire patterns occur when frequencies of two superimposed periodic patterns are close to each other.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Effect of Spatial Resolution



a	b	c
d	e	f

FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Can we increase spatial resolution by interpolation ?

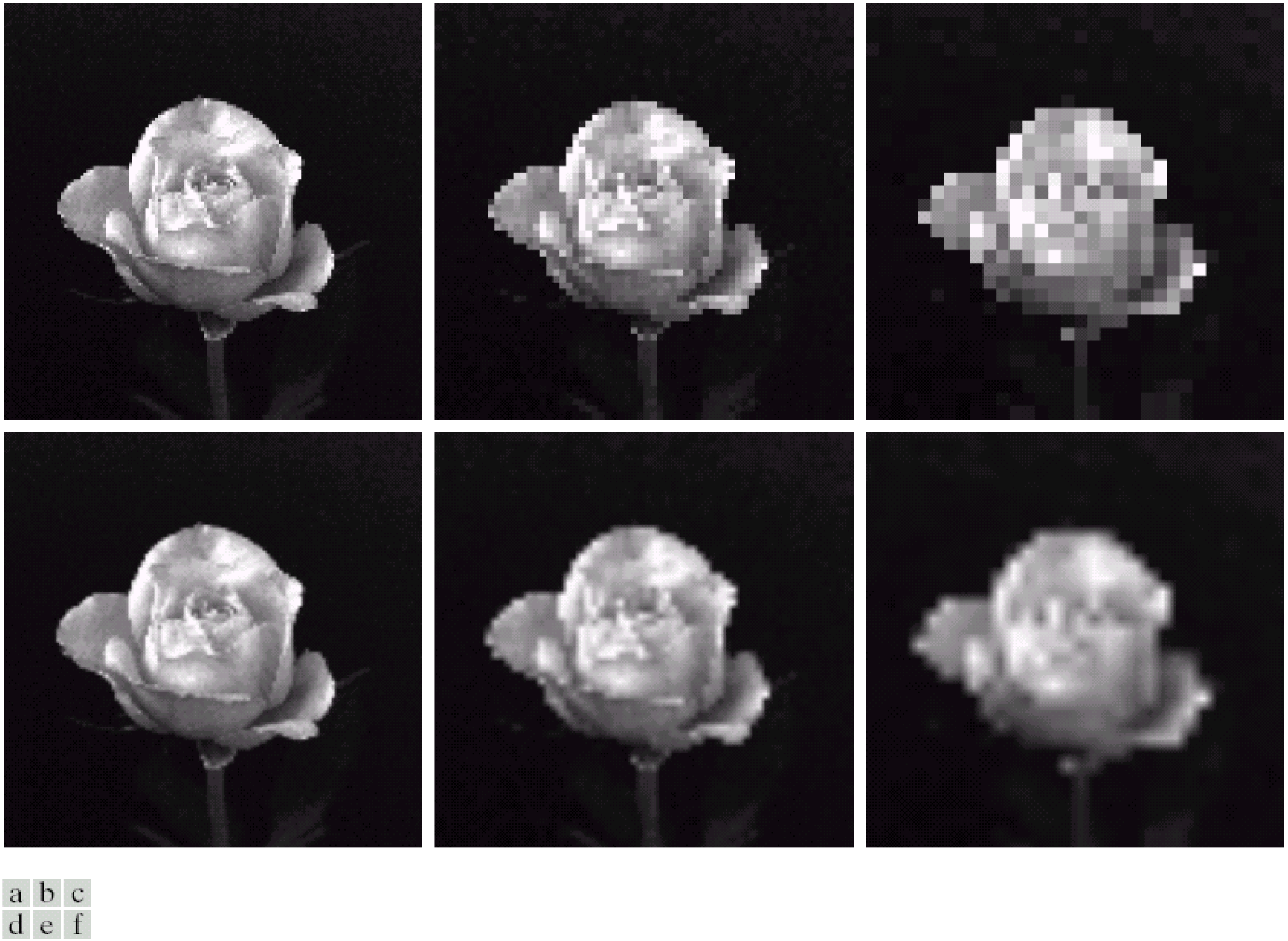


FIGURE 2.25 Top row: images zoomed from 128 × 128, 64 × 64, and 32 × 32 pixels to 1024 × 1024 pixels, using nearest neighbor gray-level interpolation. Bottom row: same sequence, but using bilinear interpolation.

Down sampling is an irreversible process.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Image Quantization

Image quantization:

discretize continuous pixel values into discrete numbers

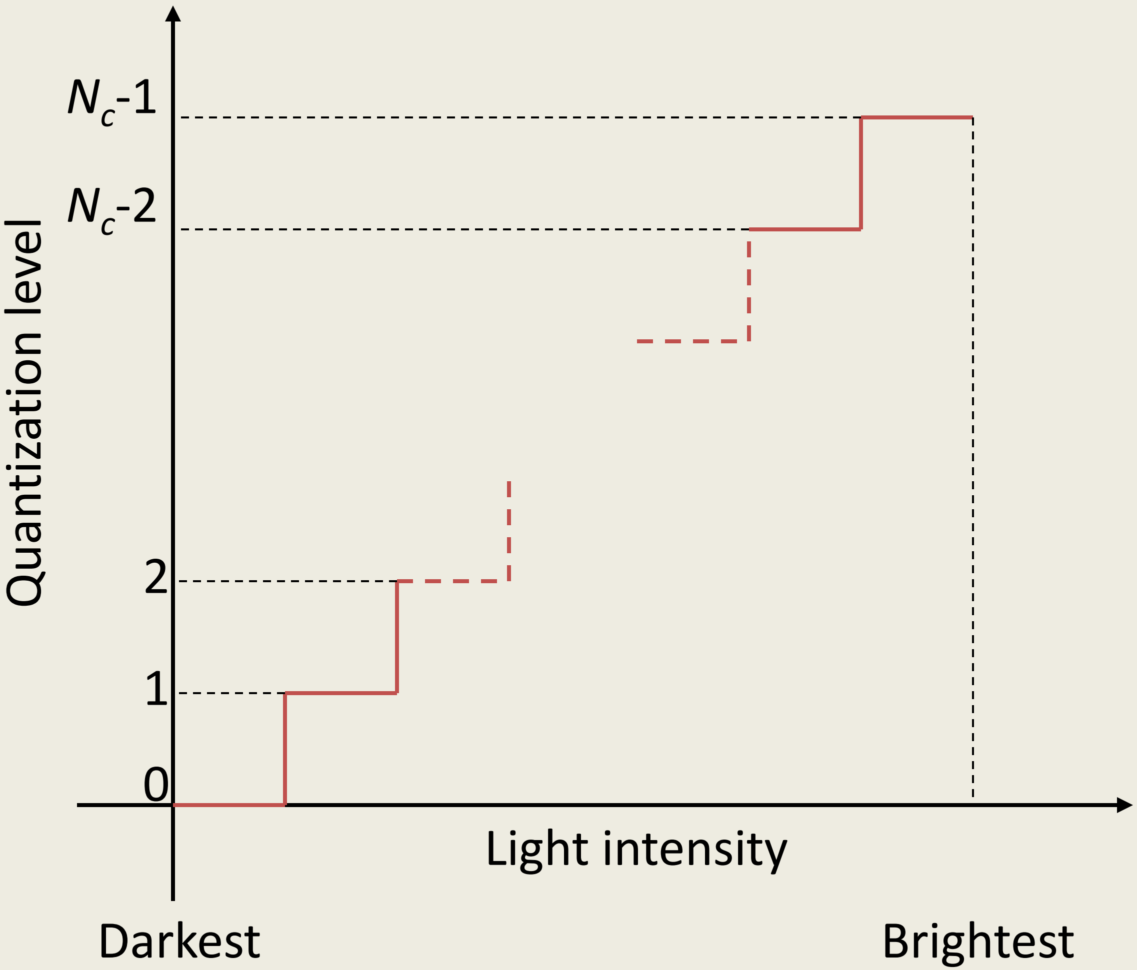
Color resolution/ color depth/ levels:

- No. of colors or gray levels or
- No. of bits representing each pixel value
- No. of colors or gray levels N_c is given by

$$N_c = 2^b$$

where b = no. of bits

Quantization function



Effect of Quantization Levels

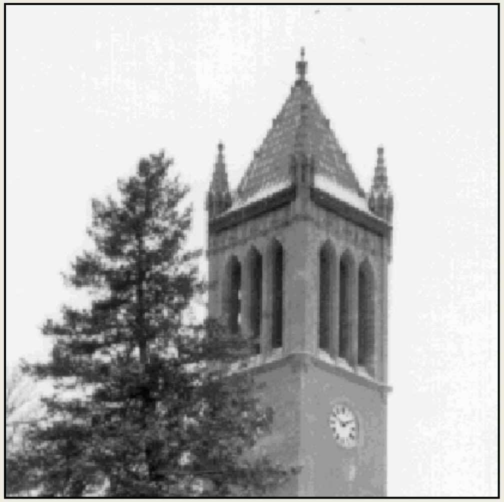
256 levels

128 levels

64 levels

32 levels

Effect of Quantization Levels (cont.)



16 levels

8 levels

In this image, it is easy to see false contour.

4 levels

2 levels

How to select the suitable size and pixel depth of images

The word “suitable” is subjective: depending on “subject”.

Low detail image

Lena image

Medium detail image

Cameraman image

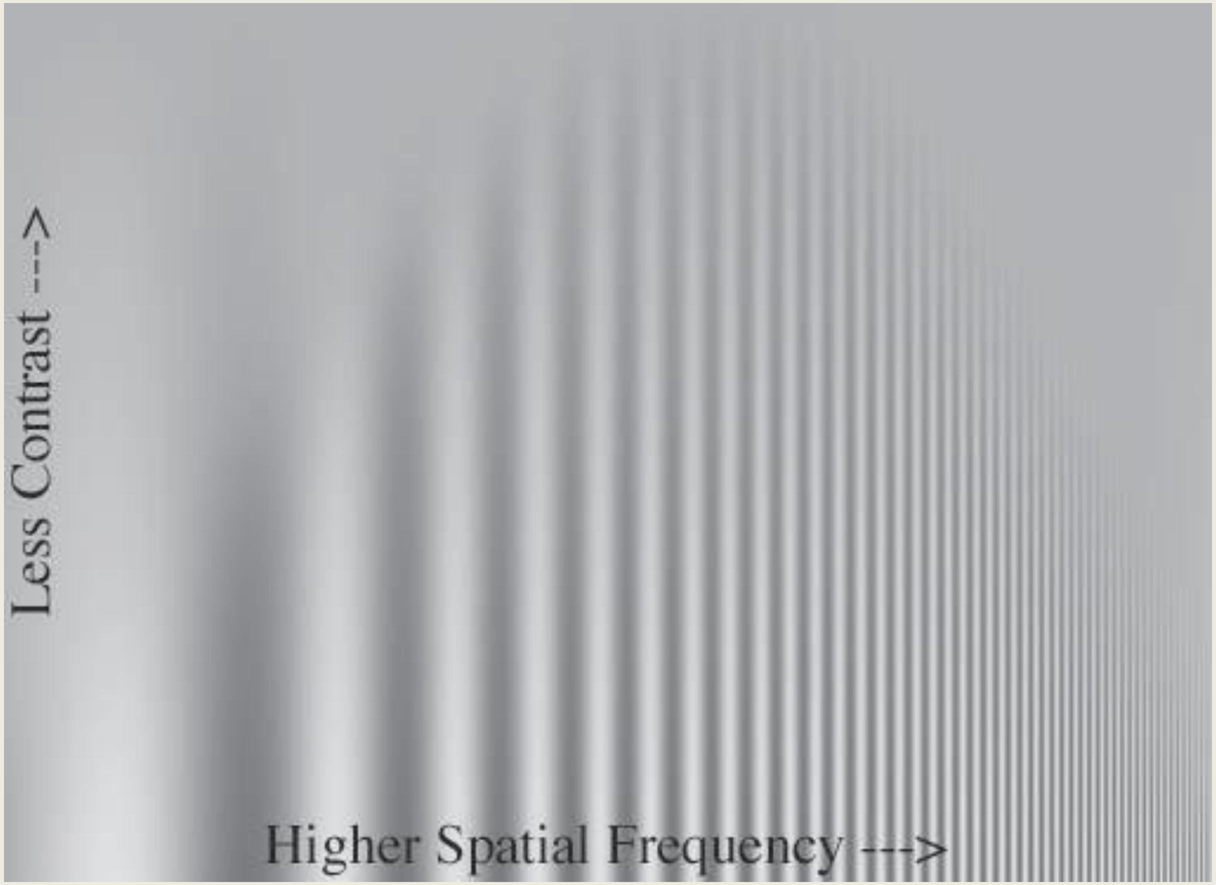
High detail image

To satisfy human mind

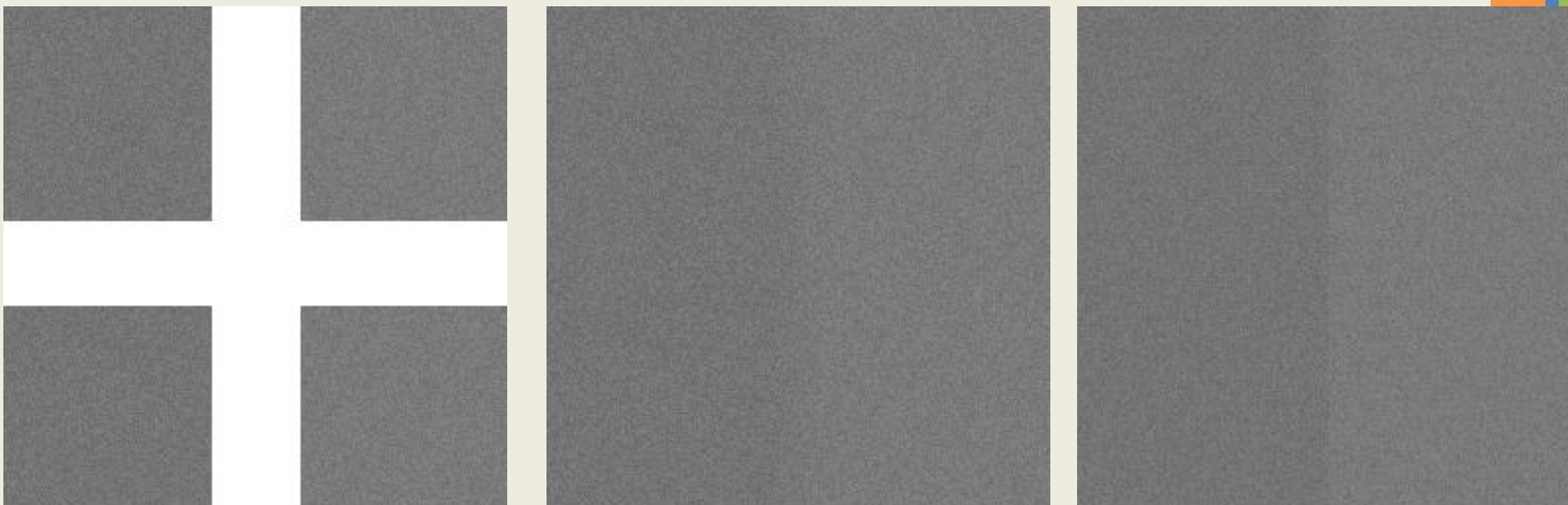
1. For images of the same size, the low detail image may need more pixel depth.
2. As an image size increase, fewer gray levels may be needed.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Human vision: Spatial Frequency vs Contrast



Human vision: Distinguish ability for Difference in brightness

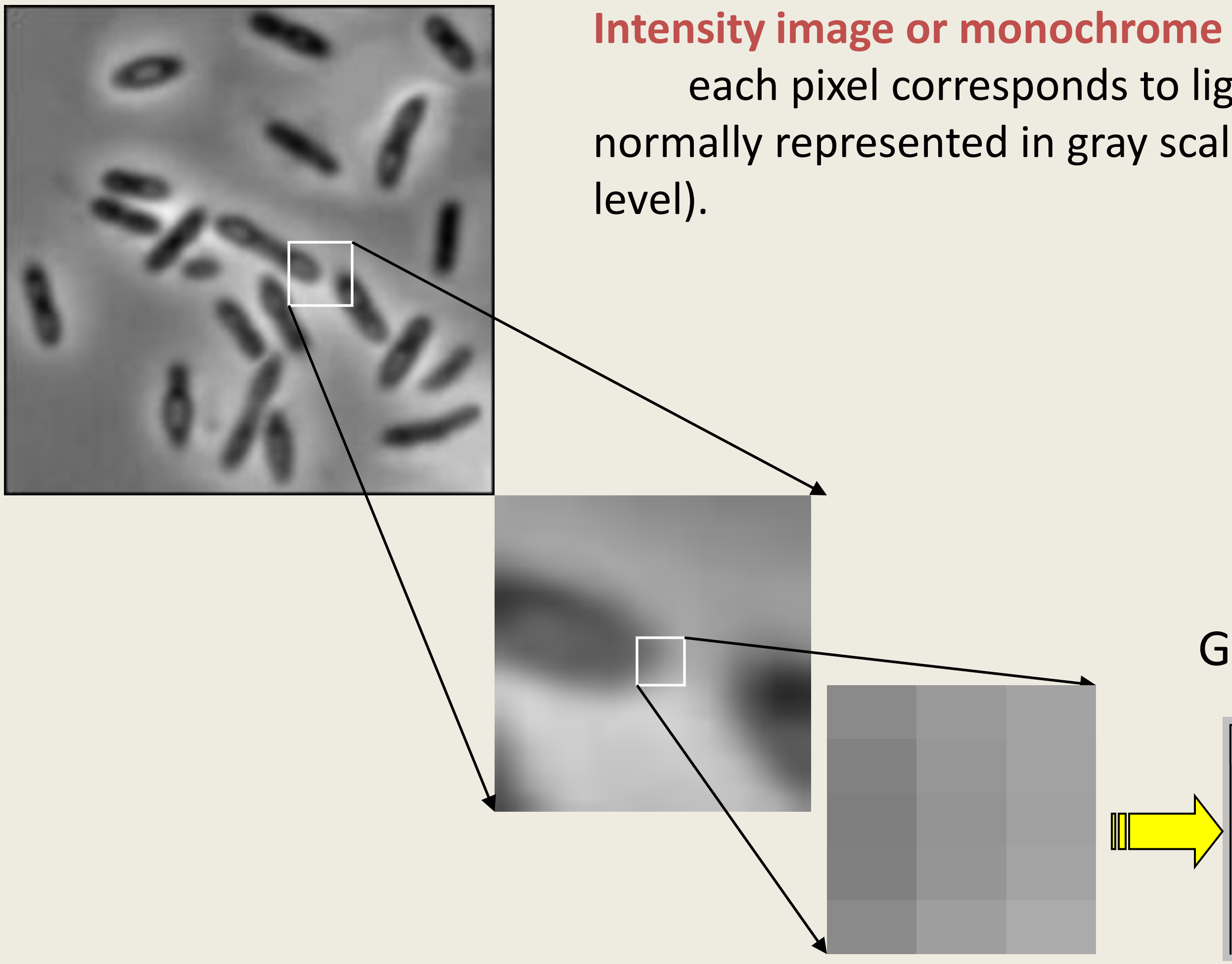


Regions with 5% brightness difference

Digital Image Types : Intensity Image

Intensity image or monochrome image

each pixel corresponds to light intensity normally represented in gray scale (gray level).

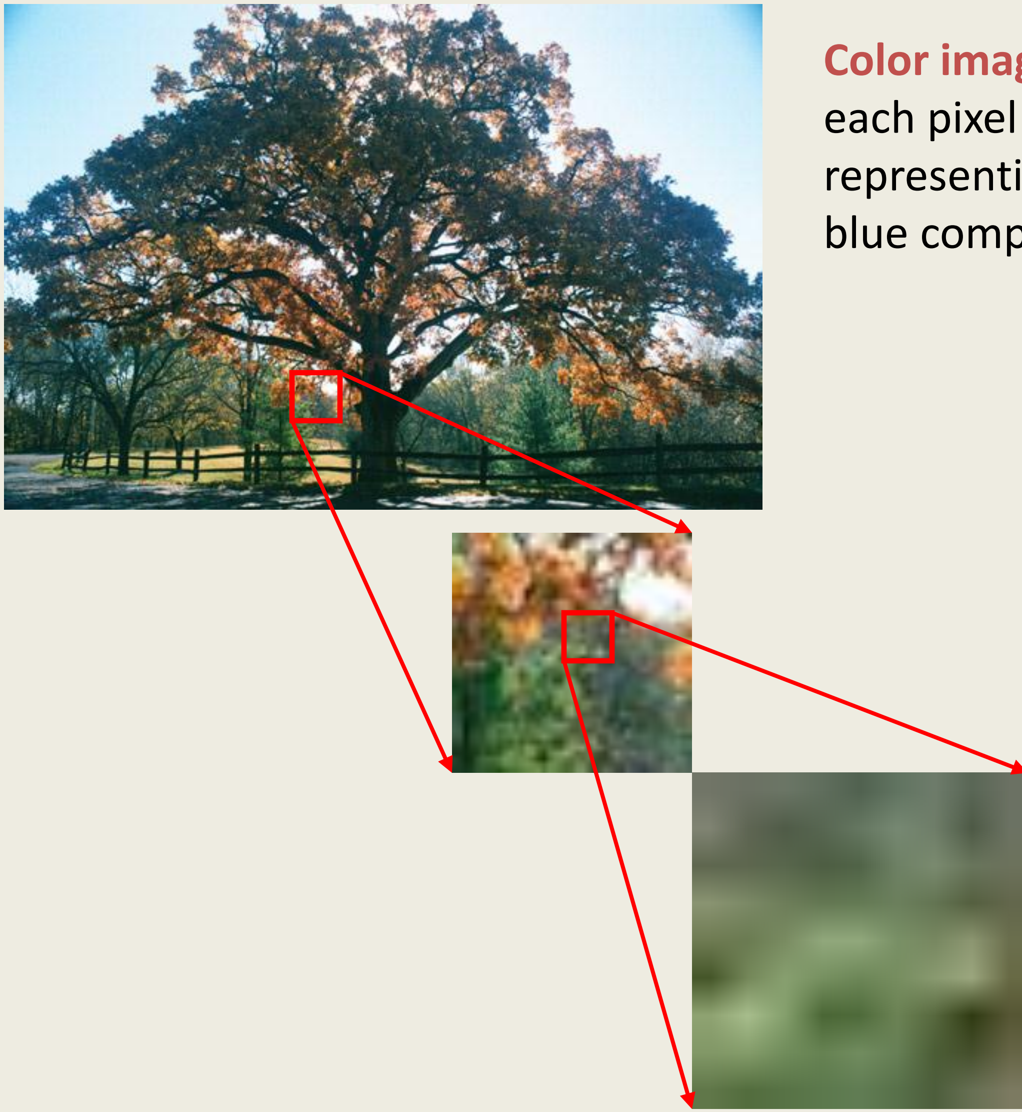


Gray scale values

$$\begin{bmatrix} 10 & 10 & 16 & 28 \\ 9 & 6 & 26 & 37 \\ 15 & 25 & 13 & 22 \\ 32 & 15 & 87 & 39 \end{bmatrix}$$

Digital Image Types : RGB Image

Color image or RGB image: each pixel contains a vector representing red, green and blue components.



RGB components

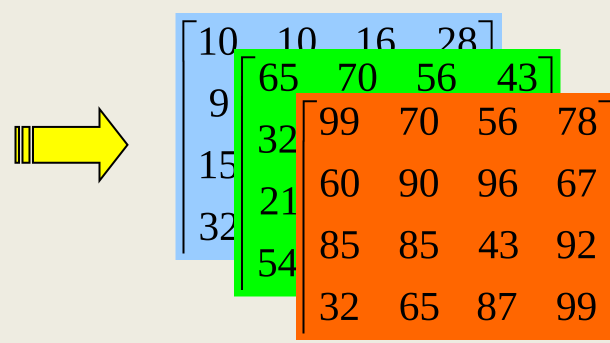


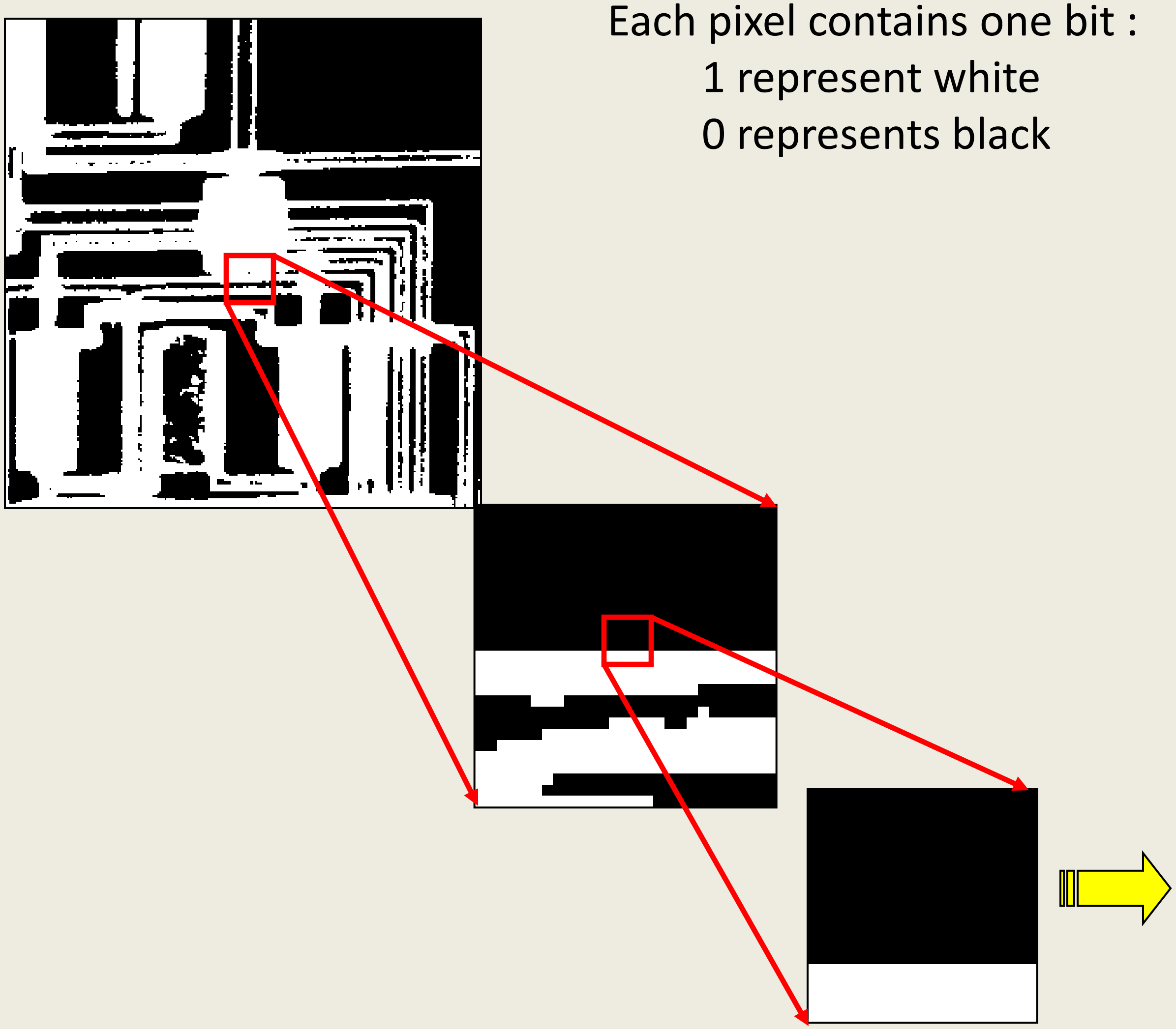
Image Types : Binary Image

Binary image or black and white image

Each pixel contains one bit :

1 represent white

0 represents black



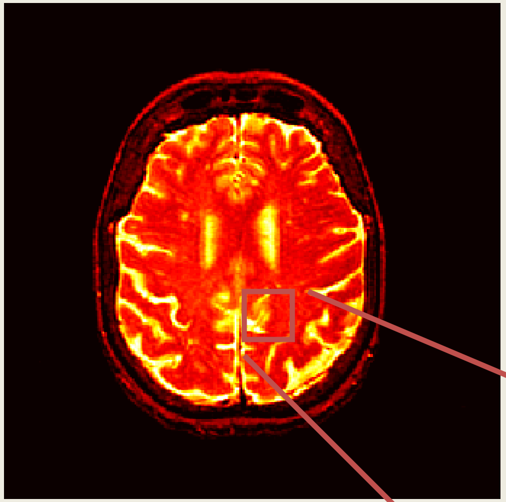
Binary data

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Image Types : Index Image

Index image

Each pixel contains index number pointing to a color in a color table



$$\begin{bmatrix} 1 & 4 & 9 \\ 6 & 4 & 7 \\ 6 & 5 & 2 \end{bmatrix}$$

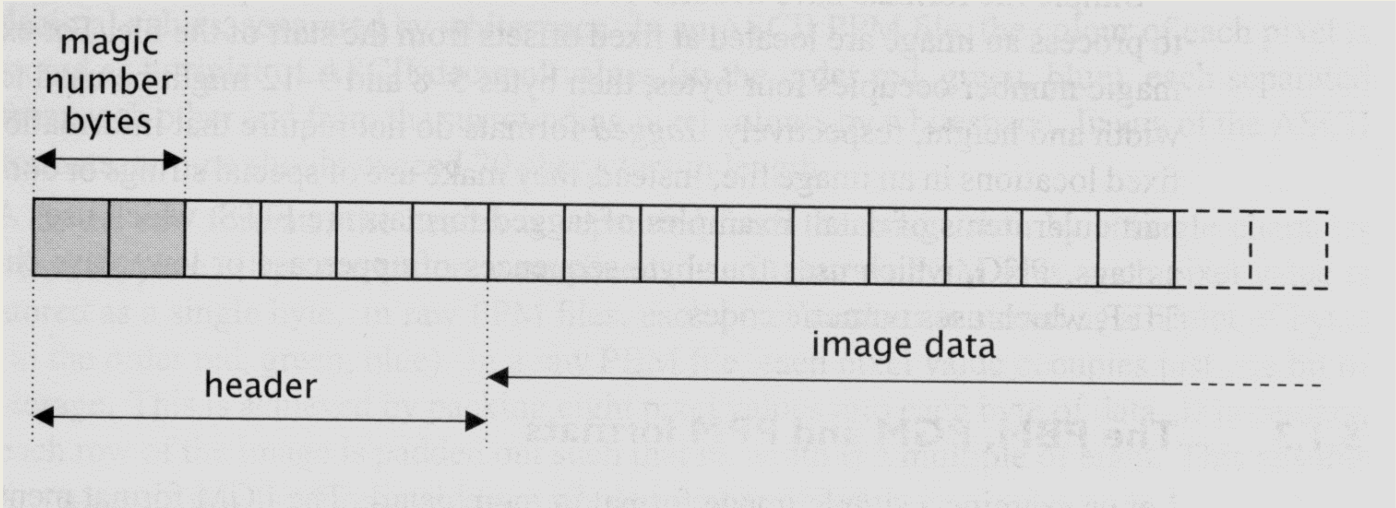
Index value

Color Table

Index No.	Red component	Green component	Blue component
1	0.1	0.5	0.3
2	1.0	0.0	0.0
3	0.0	1.0	0.0
4	0.5	0.5	0.5
5	0.2	0.8	0.9
…	…	…	…

Image file formats

- Many image formats adhere to the simple model shown below (line by line, no breaks between lines).
- The header contains at least the width and height of the image.
- Most headers begin with a **signature** or “magic number”
  (i.e., a short sequence of bytes for identifying the file format)



Common image file formats

- GIF (Graphic Interchange Format) -
- PNG (Portable Network Graphics)
- JPEG (Joint Photographic Experts Group)
- TIFF (Tagged Image File Format)
- PGM (Portable Gray Map)
- FITS (Flexible Image Transport System)

PBM/PGM/PPM format

- A popular format for grayscale images (8 bits/pixel)
- Closely-related formats are:
  - PBM (Portable Bitmap), for binary images (1 bit/pixel)
  - PPM (Portable Pixelmap), for color images (24 bits/pixel)

ASCI

```
P2
# a simple PGM image
7 7 255
  120 120 120 120 120 120 120
  120 120 120  33 120 120 120
  120 120 120  33 120 120 120
  120  33  33  33  33  33 120
  120 120 120  33 120 120 120
  120 120 120  33 120 120 120
  120 120 120 120 120 120 120
```

Binary

```
P5
# a simple PGM image
7 7 255
xxxxxxxxxx!xxxxxx!xxxx!!!!!xxxx!xxxxxx!xxxxxxxxxx
```

ASCII or binary (raw) storage

Signatures of the various PBM, PGM and PPM image formats.

Signature	Image type	Storage type
P1	binary	ASCII
P2	greyscale	ASCII
P3	RGB	ASCII
P4	binary	raw bytes
P5	greyscale	raw bytes
P6	RGB	raw bytes