10301373 Image Processing

Chapter 1

Human visual perception

And

Image Acquisition

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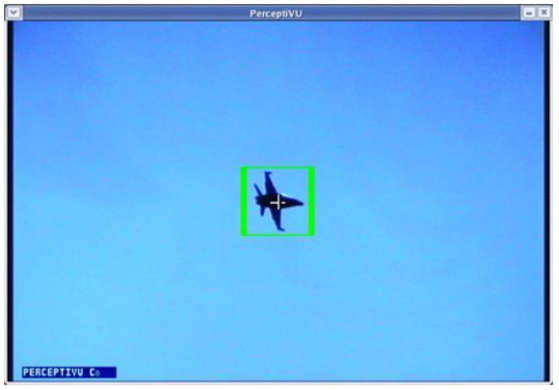
Computer Science MJU

What is image processing ?

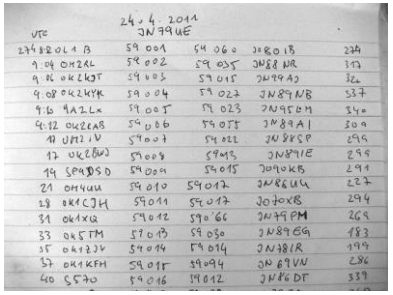


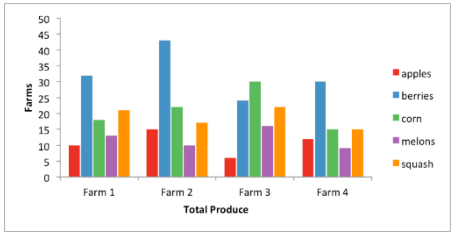
Input = ?

Output =?

The universe of digital imagery

Parameter → Computer Graphics → Image





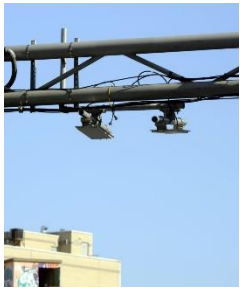
computer graphics

The universe of digital imagery

Image → Image Processing → Image

The universe of digital imagery

computer graphics



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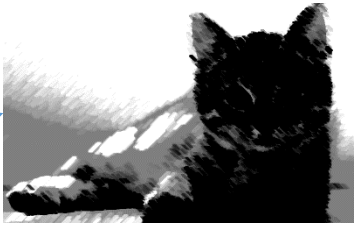
The universe of digital imagery

In imaging science,**image processing** is processing of images using mathematical operations by using any form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image

Image Processing

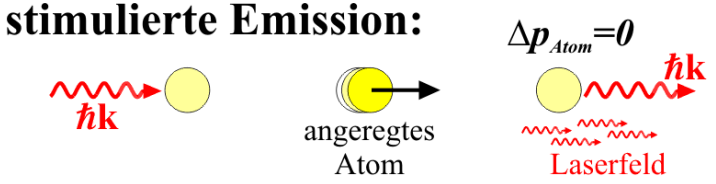


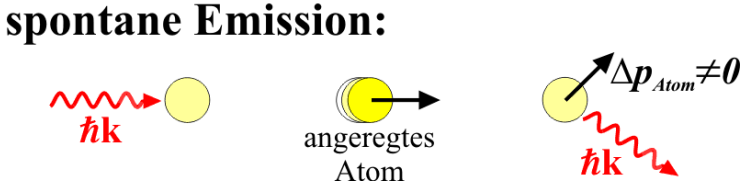
CAT

We percept image through our eyes

Our eyes sense light

Percept image = Percept light

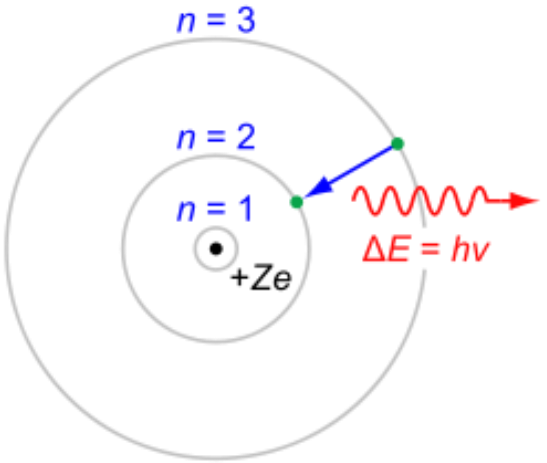


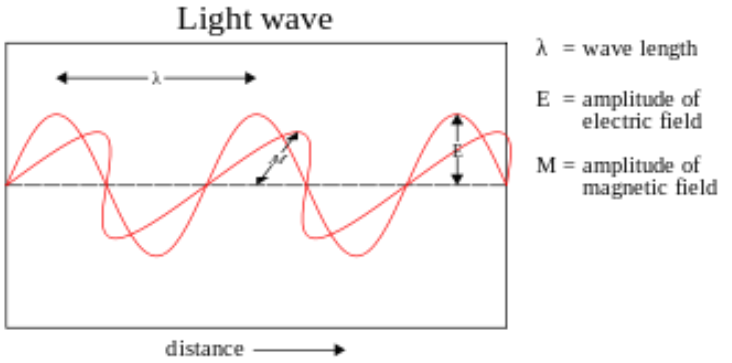


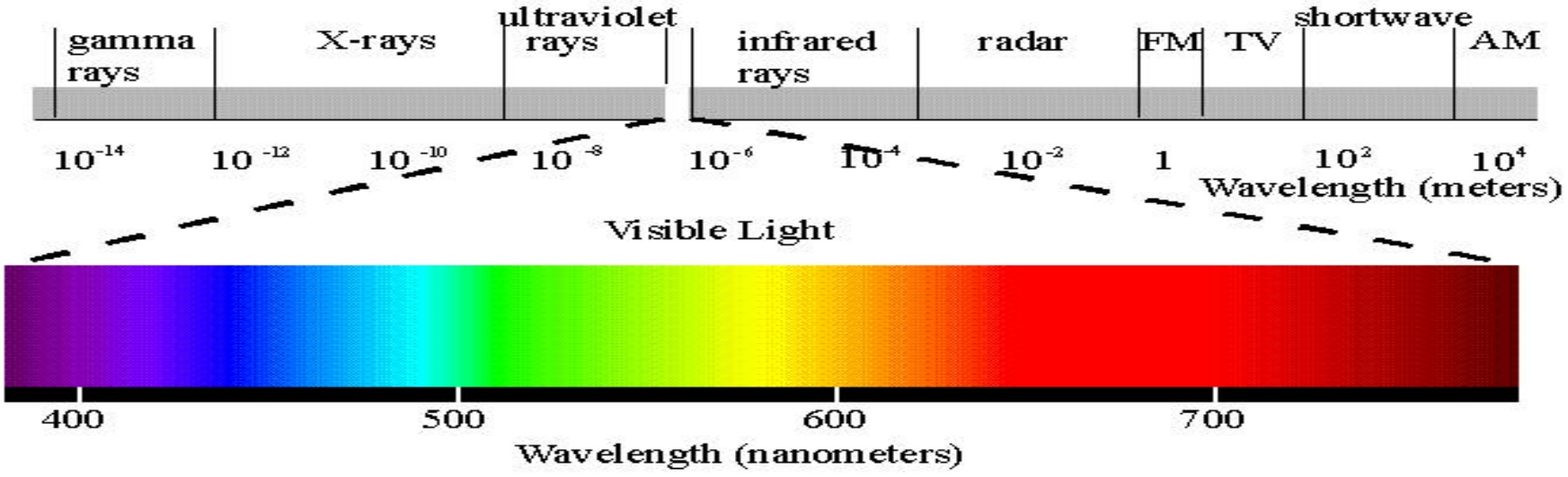
What is light

-Electromagnetic radiation that is visible to the human eye

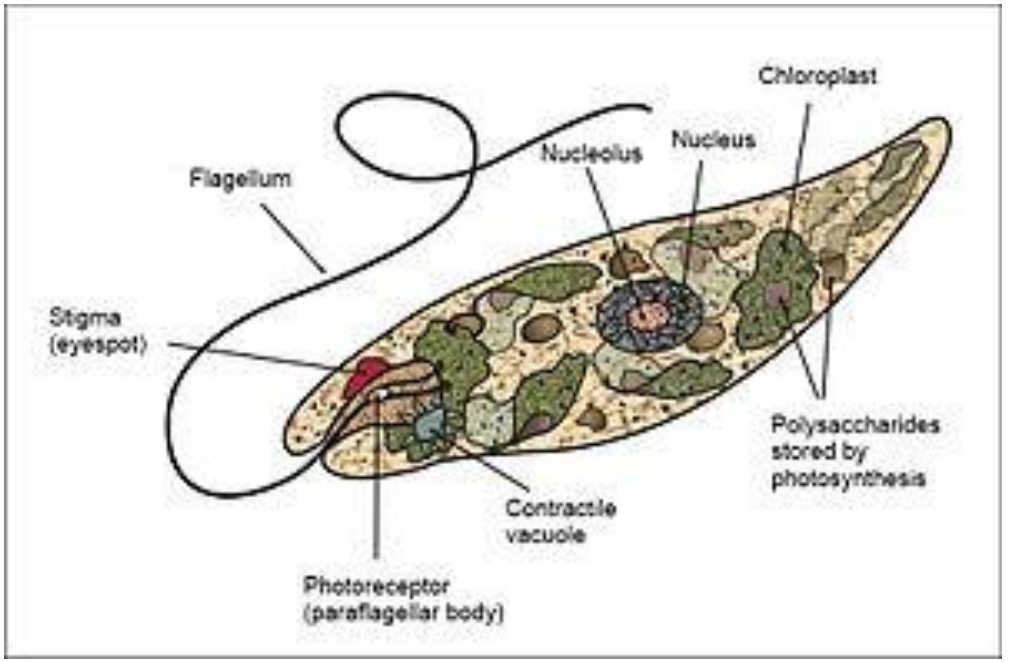
-Can be wave or particle



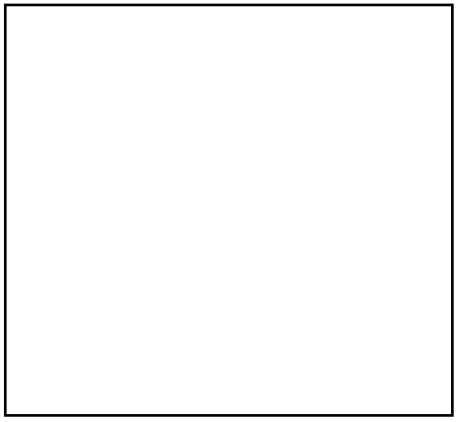




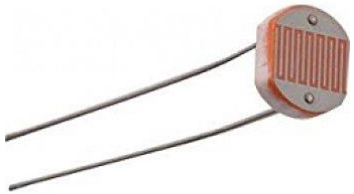
How eye works (Photoreceptor)



Euglena



How eye works (Photoreceptor)

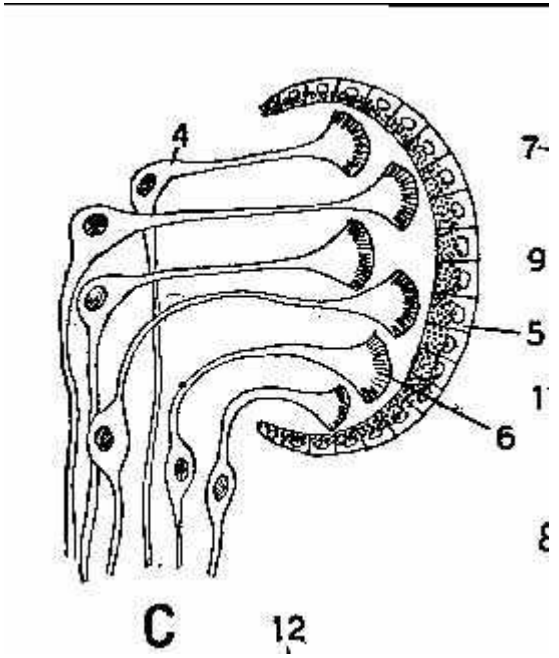


Light Dependent Resistor

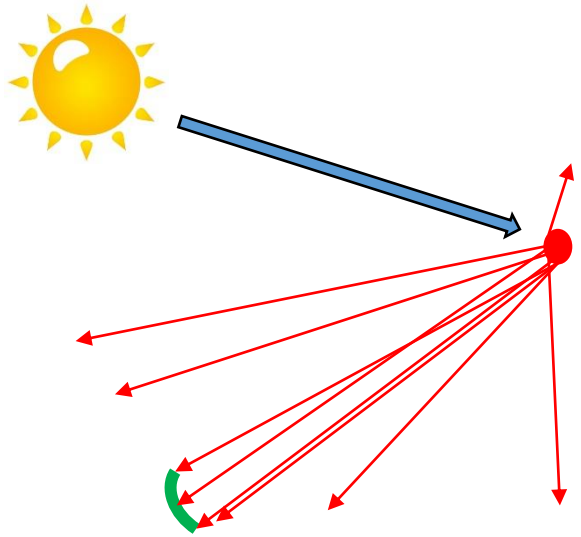
Photo Transistor

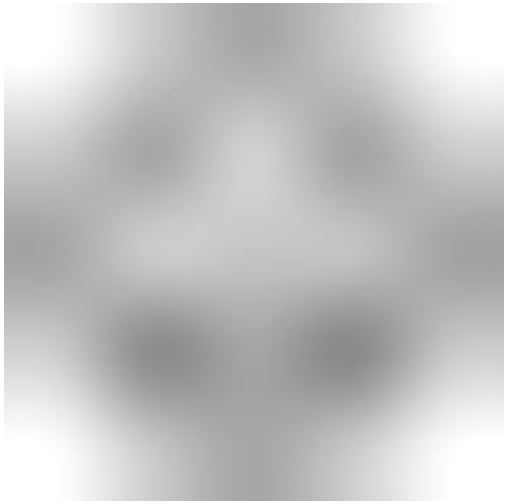
Passive InfraRed sensor

How eye works (Eye cup)

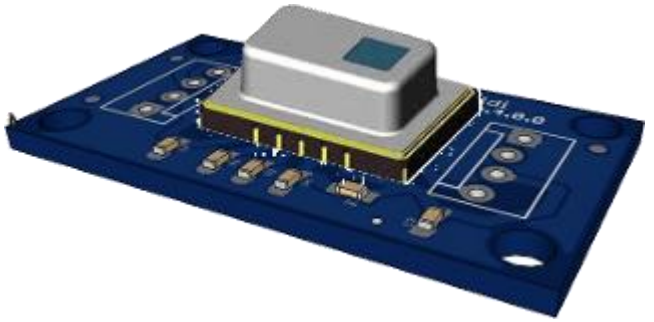


Planarian



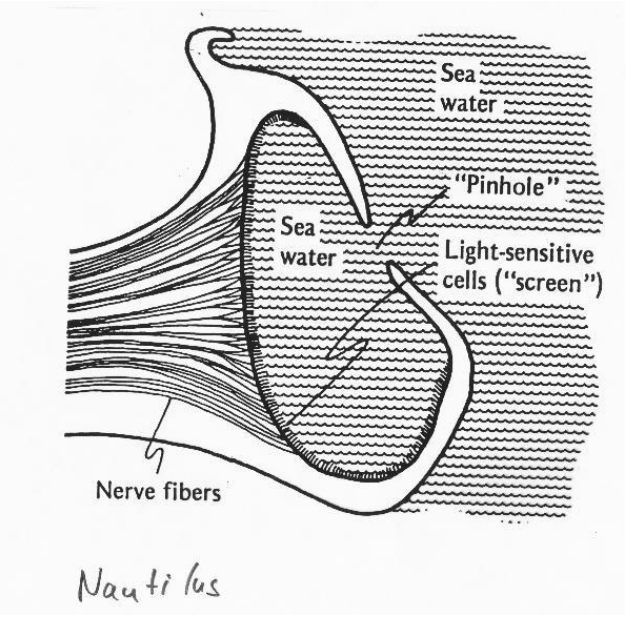


How eye works (Eye cup)

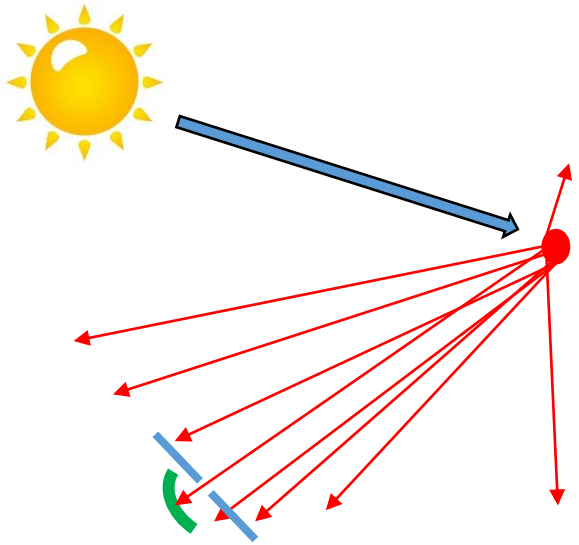


8x8 PIR sensor array

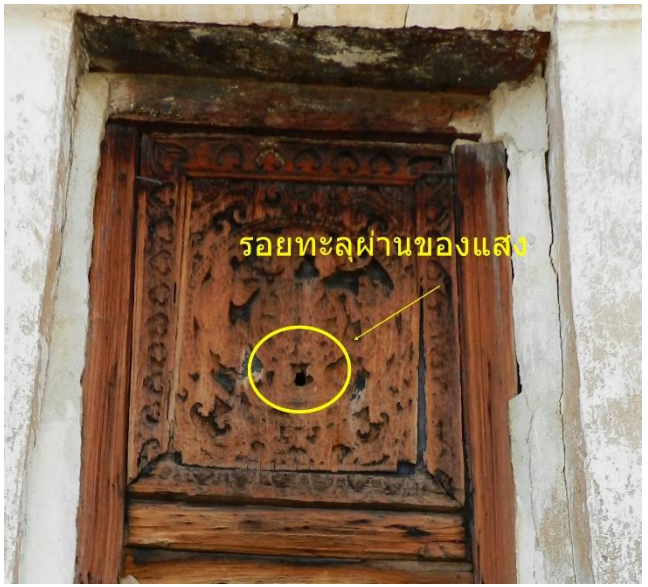
How eye works (Pinhole)



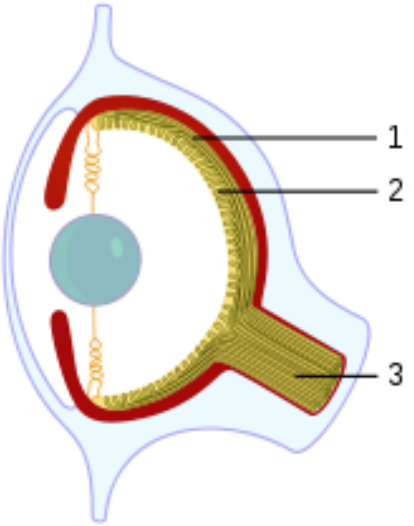
Nautilus belauensis



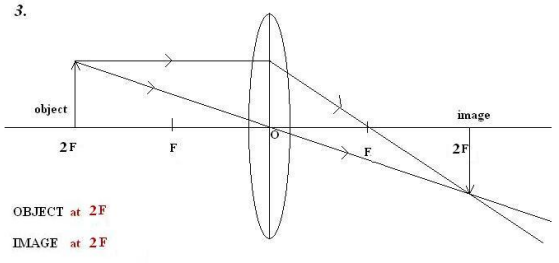
How eye works (Pinhole)



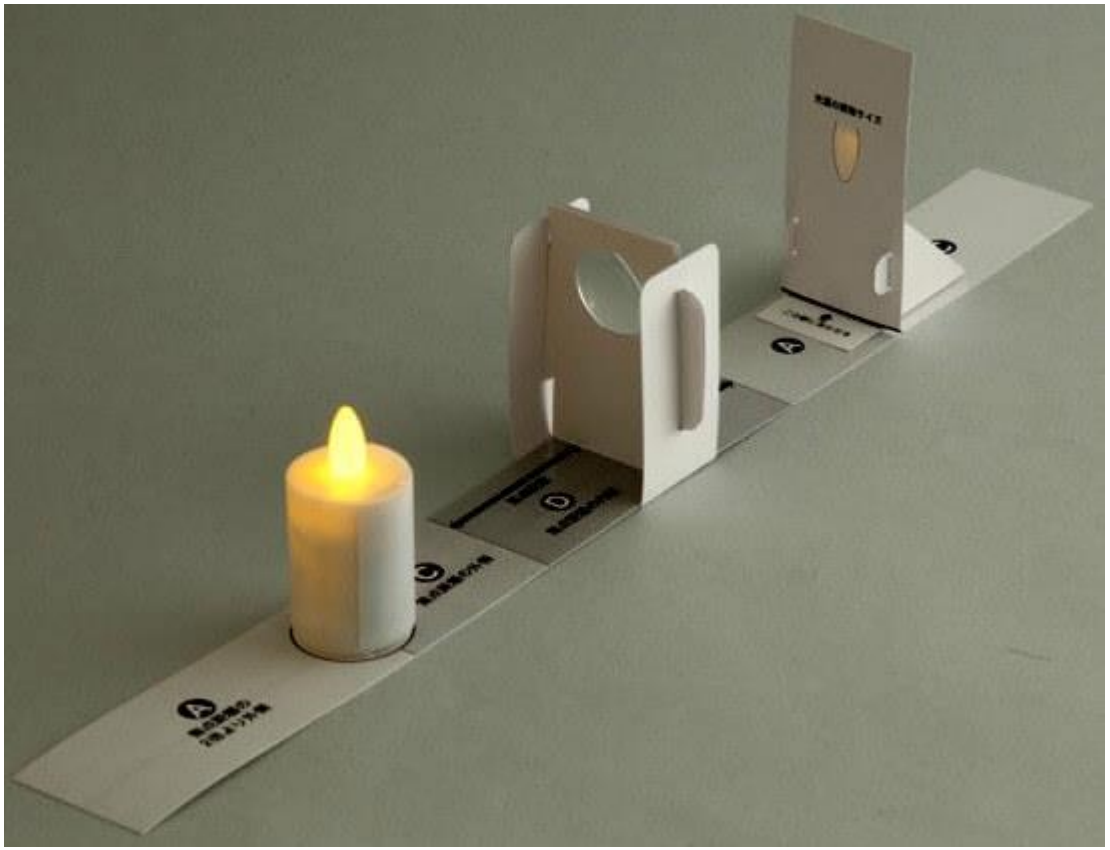
How eye works (Lens)



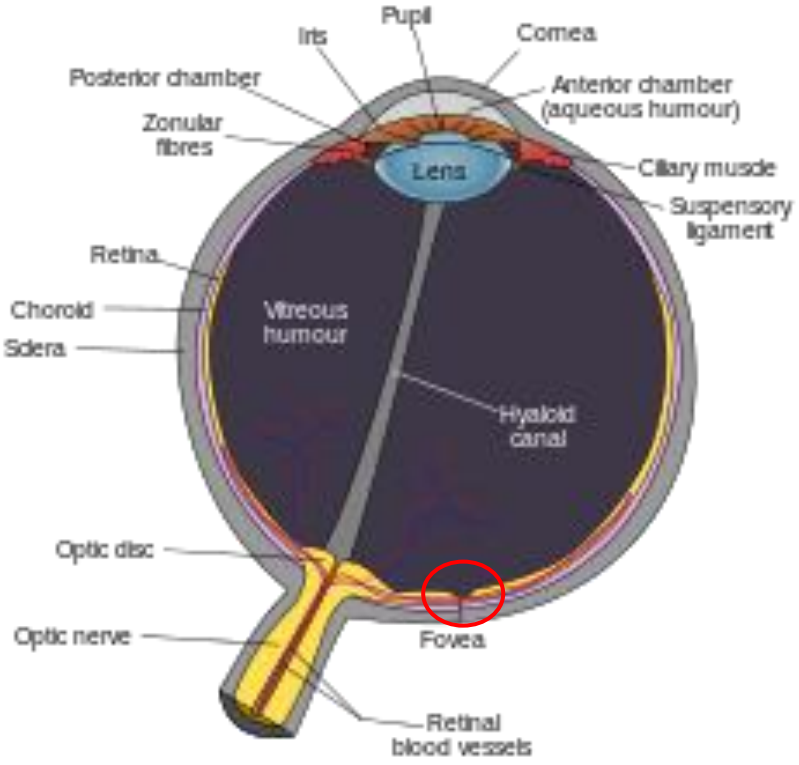
Octopus



How eye works (Lens)



How eye works (Foveated Imaging)



Human eye

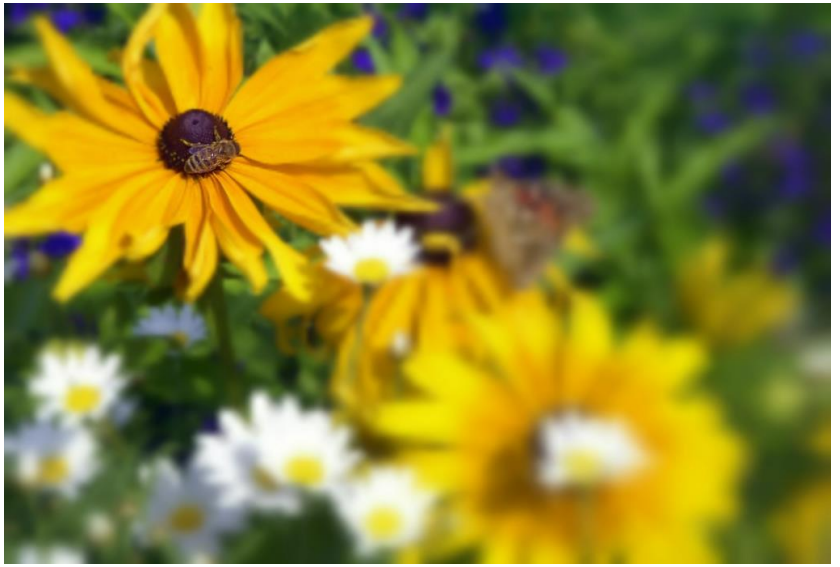
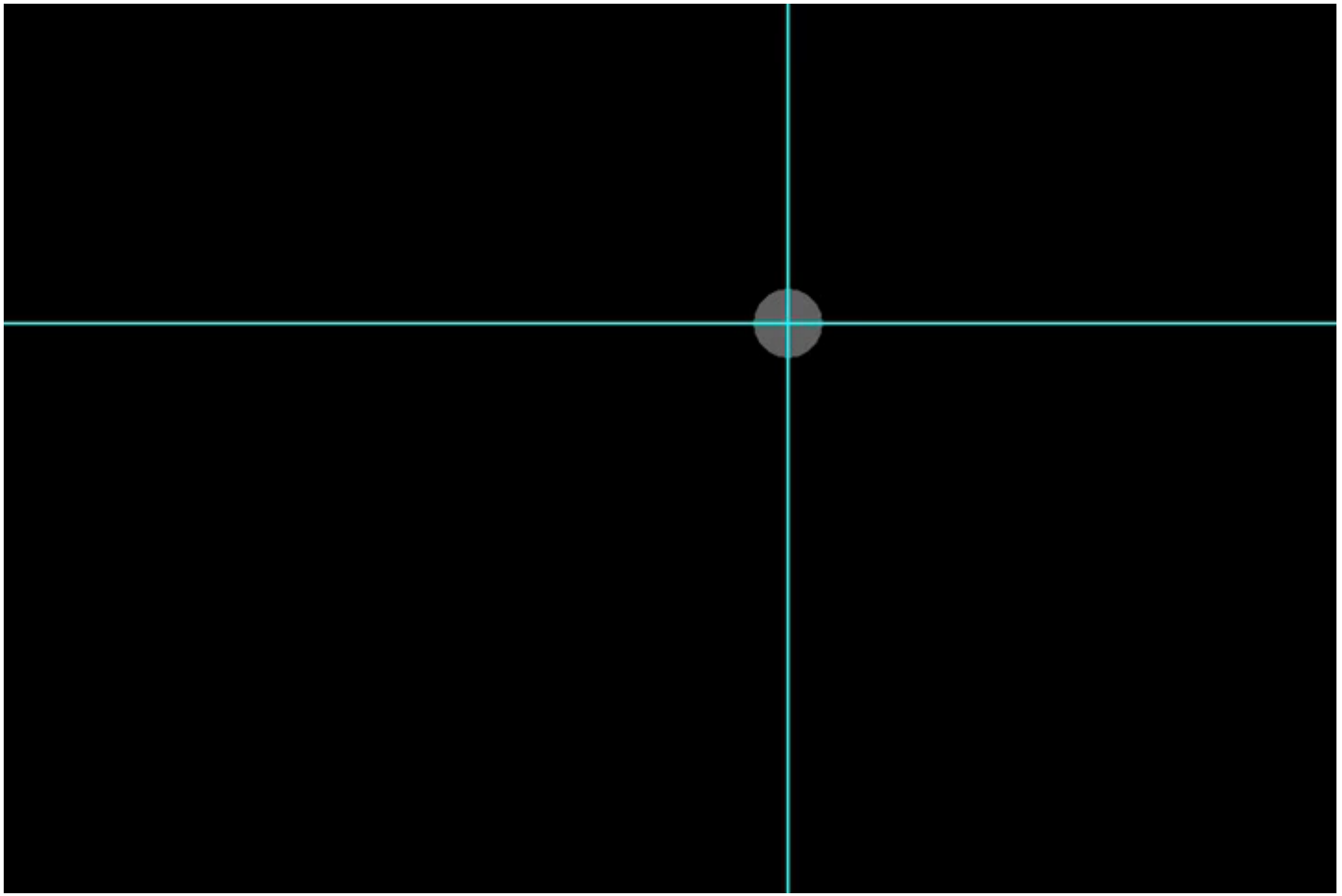
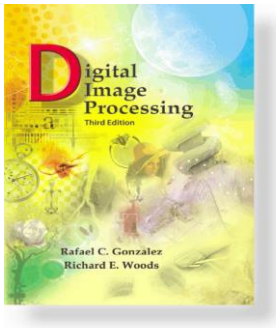


Image formed

Foveated Imaging





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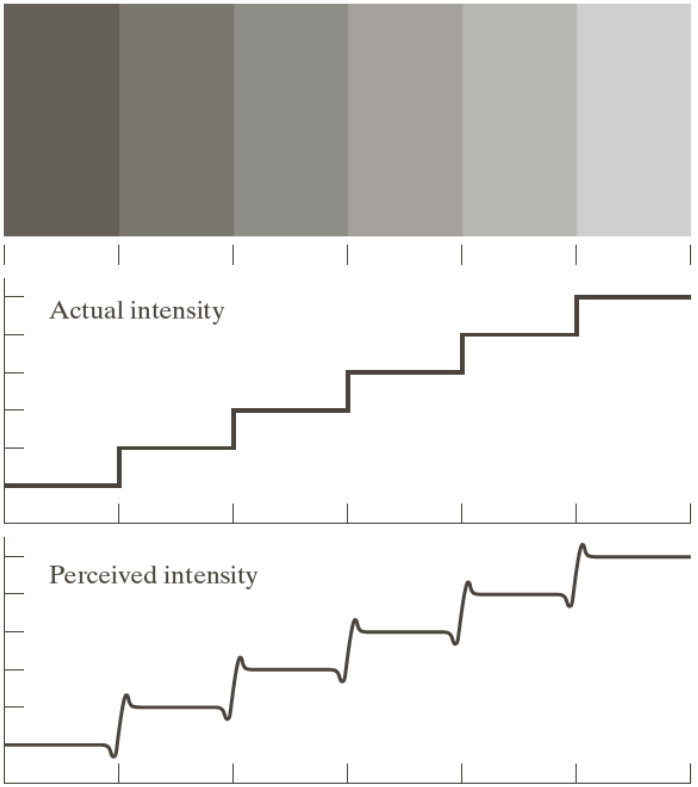
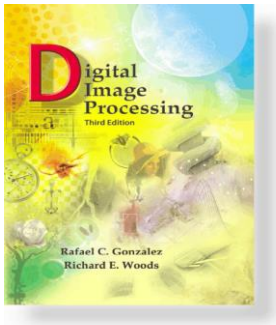


a
b
c

FIGURE 2.7 Illustration of the Mach band effect. Perceived intensity is not a simple function of actual intensity.



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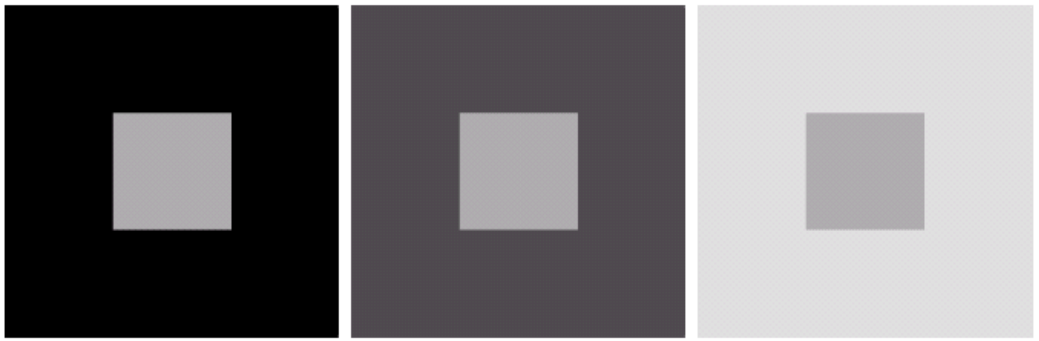
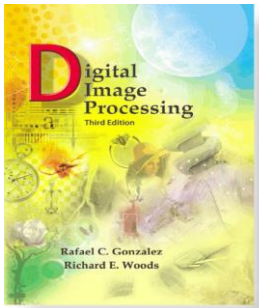


a b c

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.



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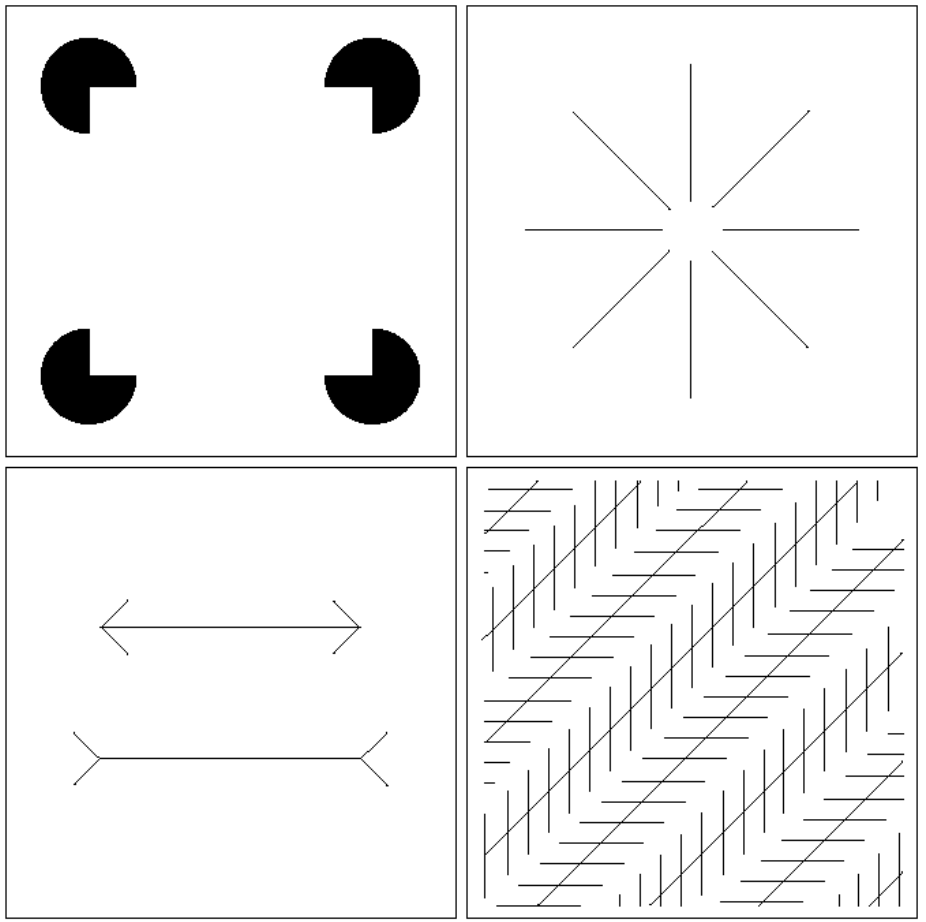
a b
c d

FIGURE 2.9 Some well-known optical illusions.



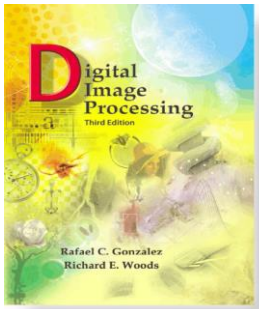


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FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])

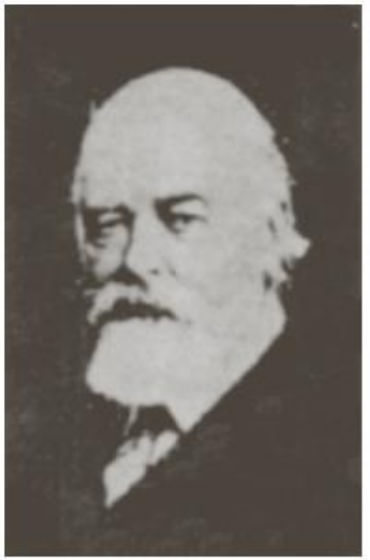
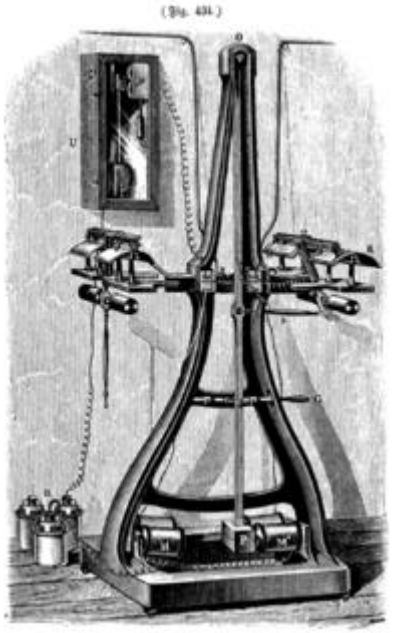


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)



Giovanni Caselli's pantelegraph

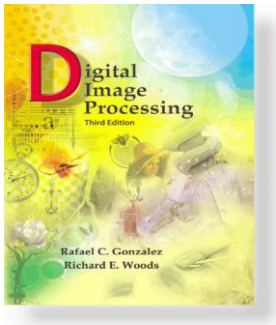


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FIGURE 1.3 Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

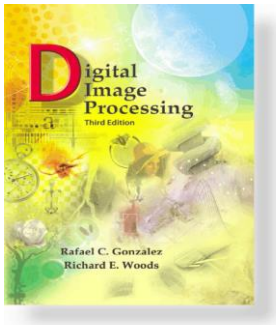

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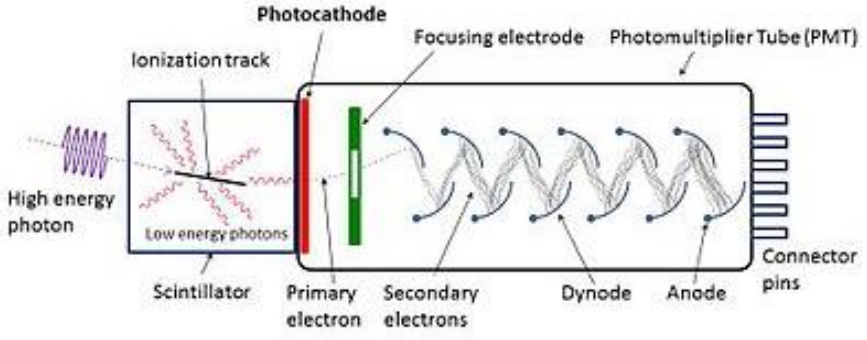
FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9 : 09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

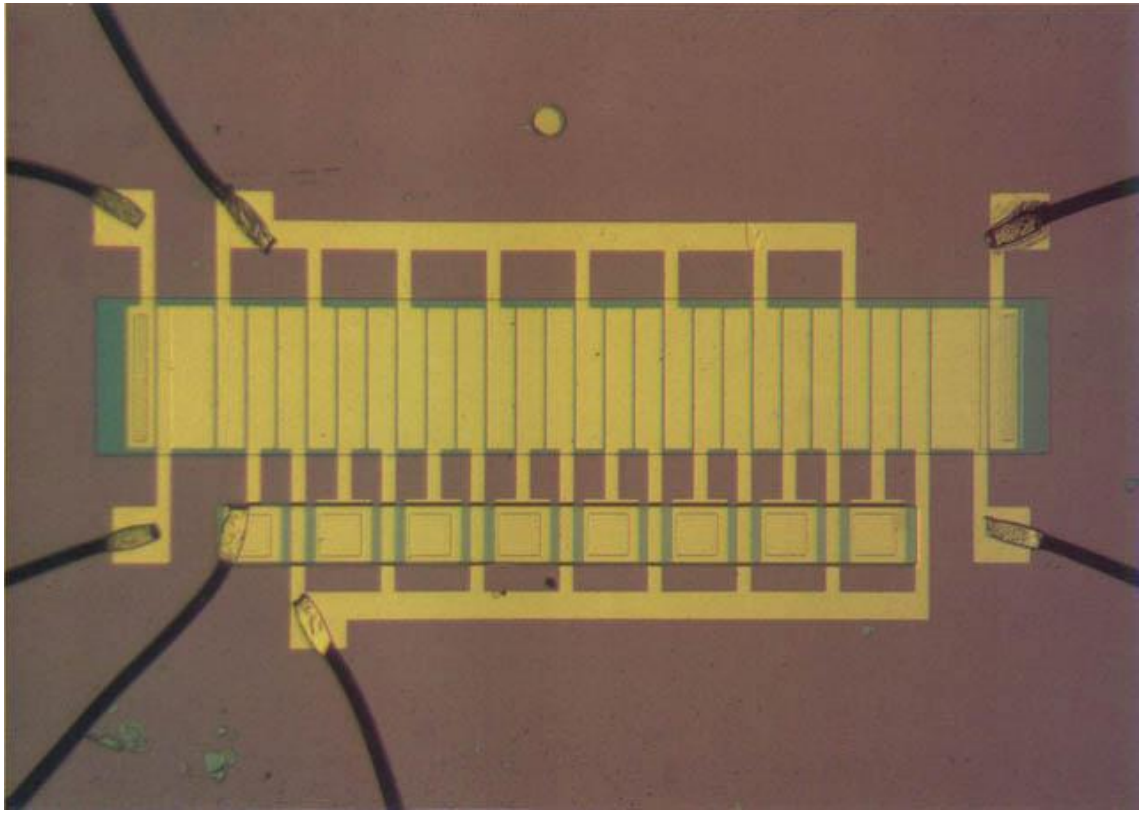
The first digital scanned image

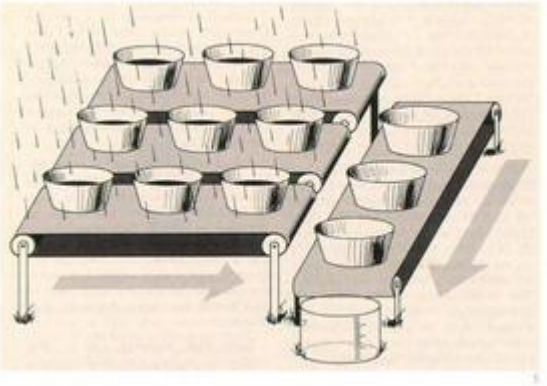
Russell A. Kirsch

The first photographs scanned in 1957, a picture of Kirsch's three-month-old son, was captured as just 30,976 pixels, a 176 × 176 array, in an area measuring 5 cm × 5 cm.

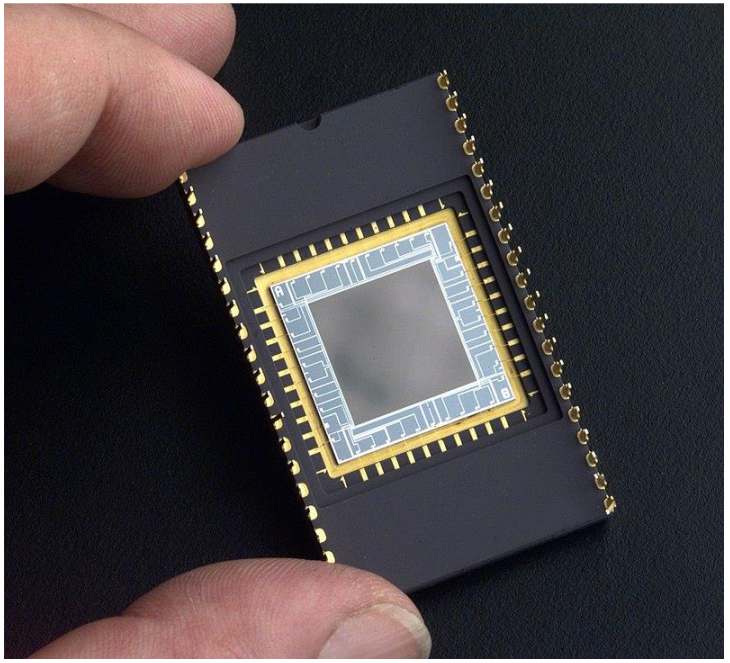


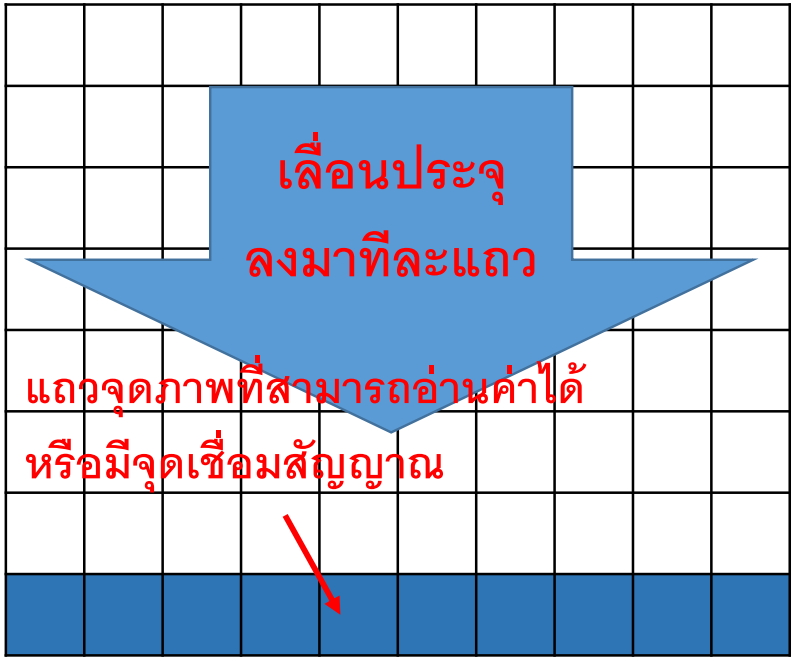
Photomultiplier tubes



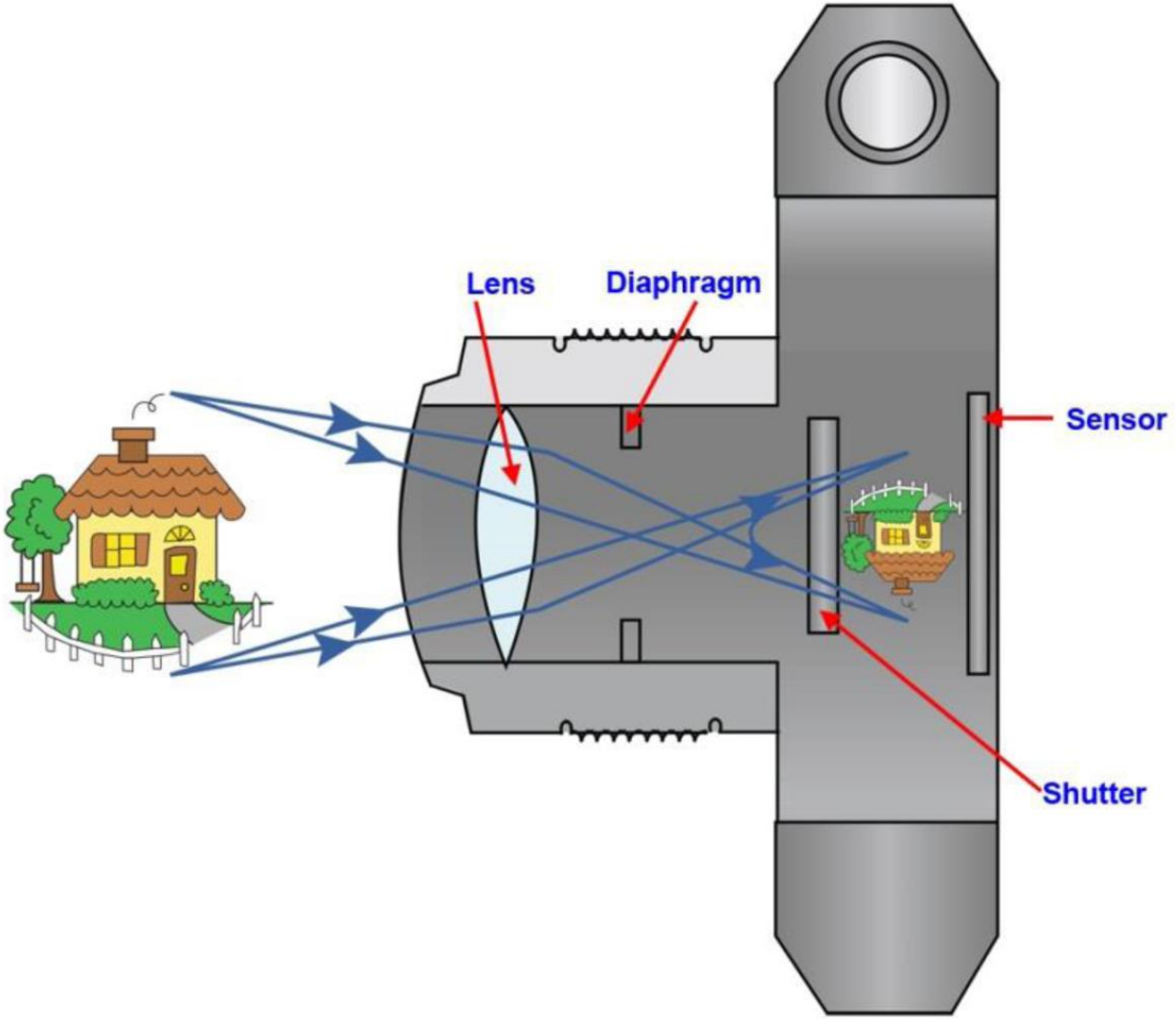


The first 8-bit CCD, this chip consists of twenty-four closely packed MOS capacitors (the narrow rectangles in the football-field-like grid in the center). The thick rectangles at either end of the grid are input/output terminals. This chip can detect and reproduce simple images, like the letters CCD. Today's CCDs can store up to 64K bits of data. Actual size: 0.060 x 0.100 inches.




เลื่อนประจุ
ลงมาทีละแถว
แถวจุดภาพที่สามารถอ่านค่าได้
หรือมีจุดเชื่อมสัญญาณ

Digital Camera



Camera body

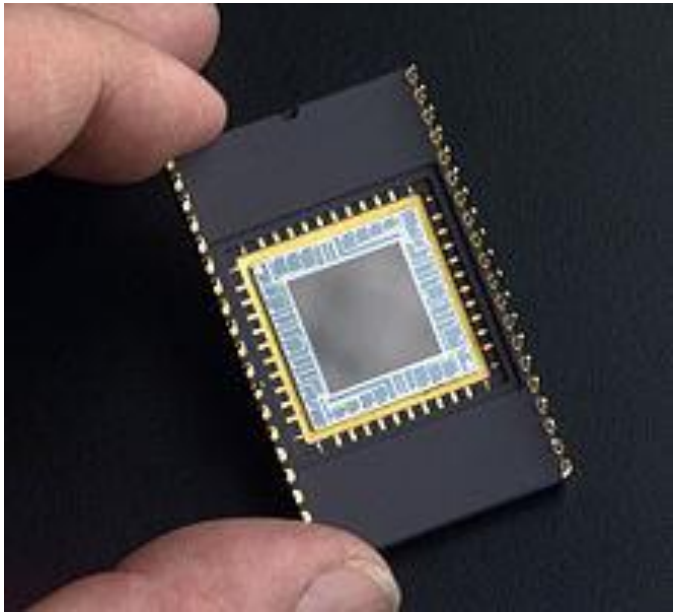
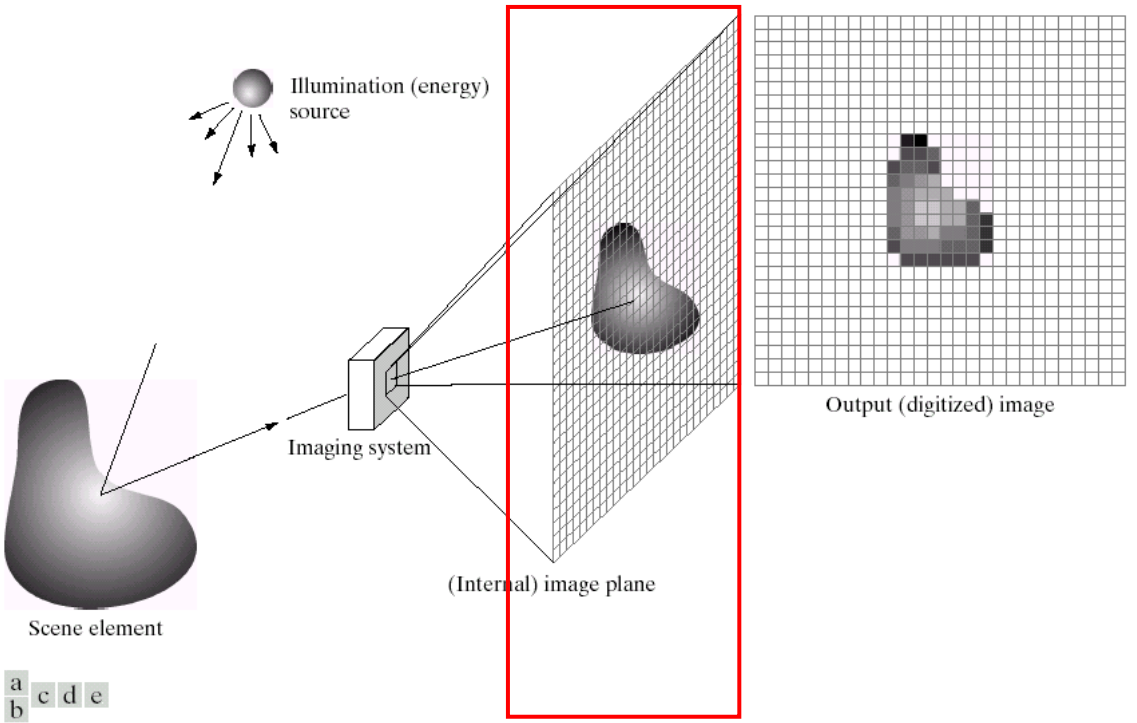
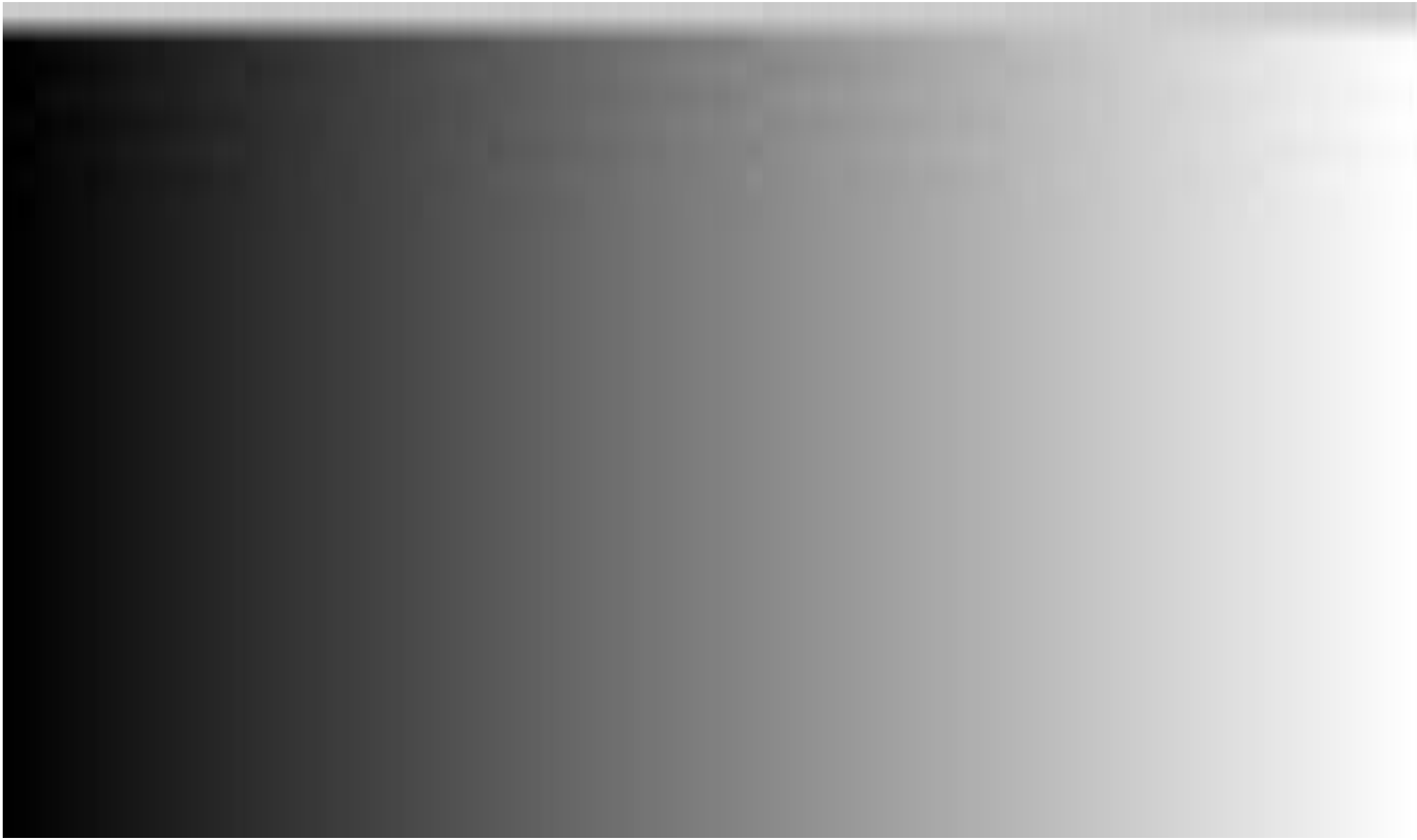


Image Sensor

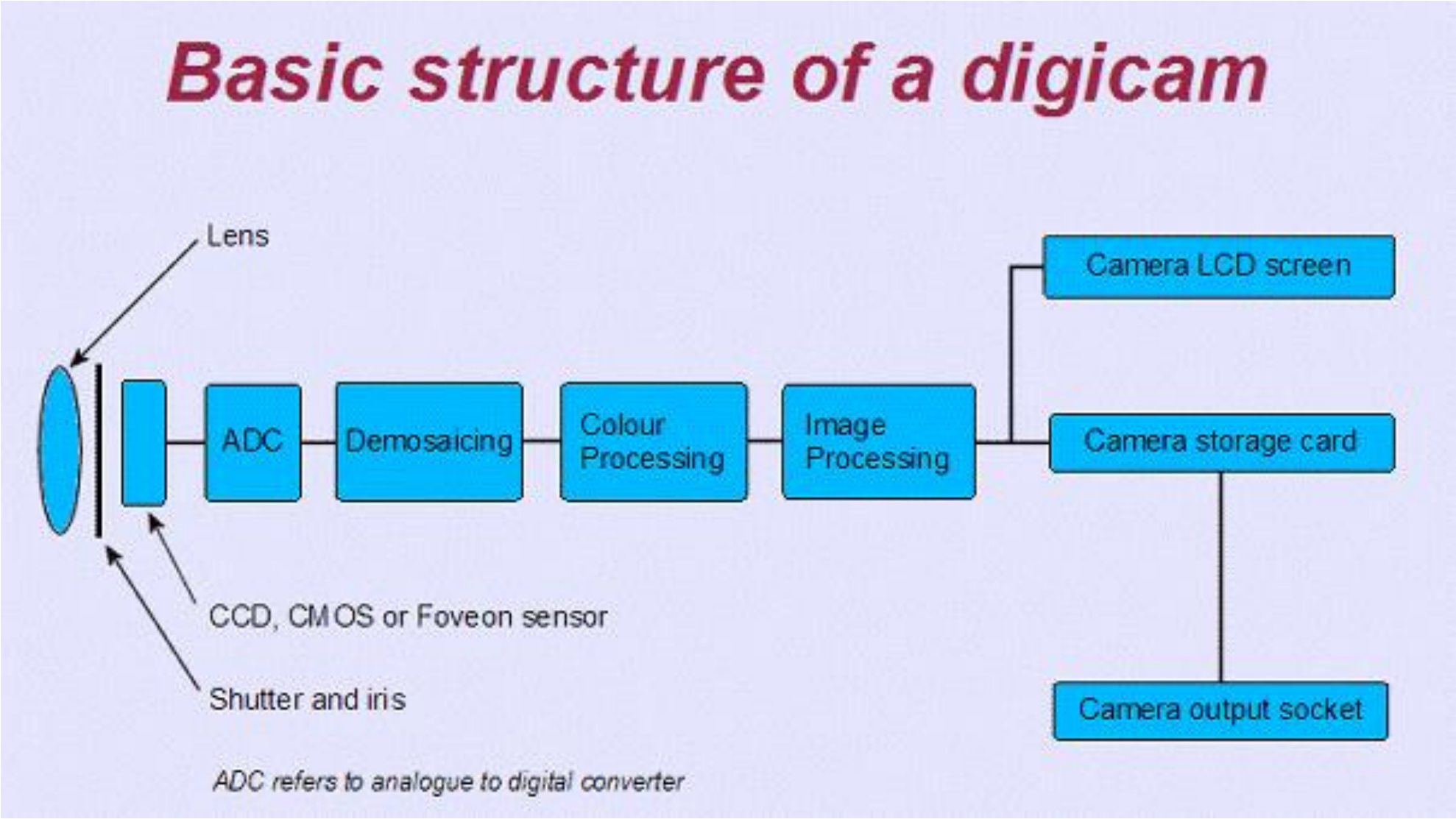


a
b c d e

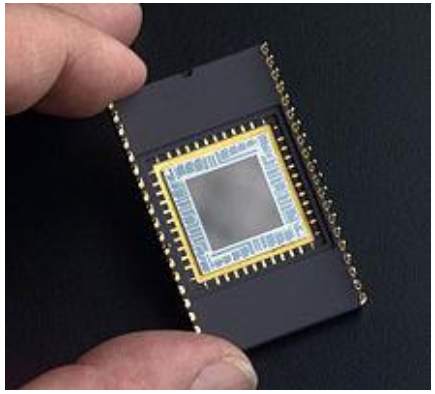
FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.



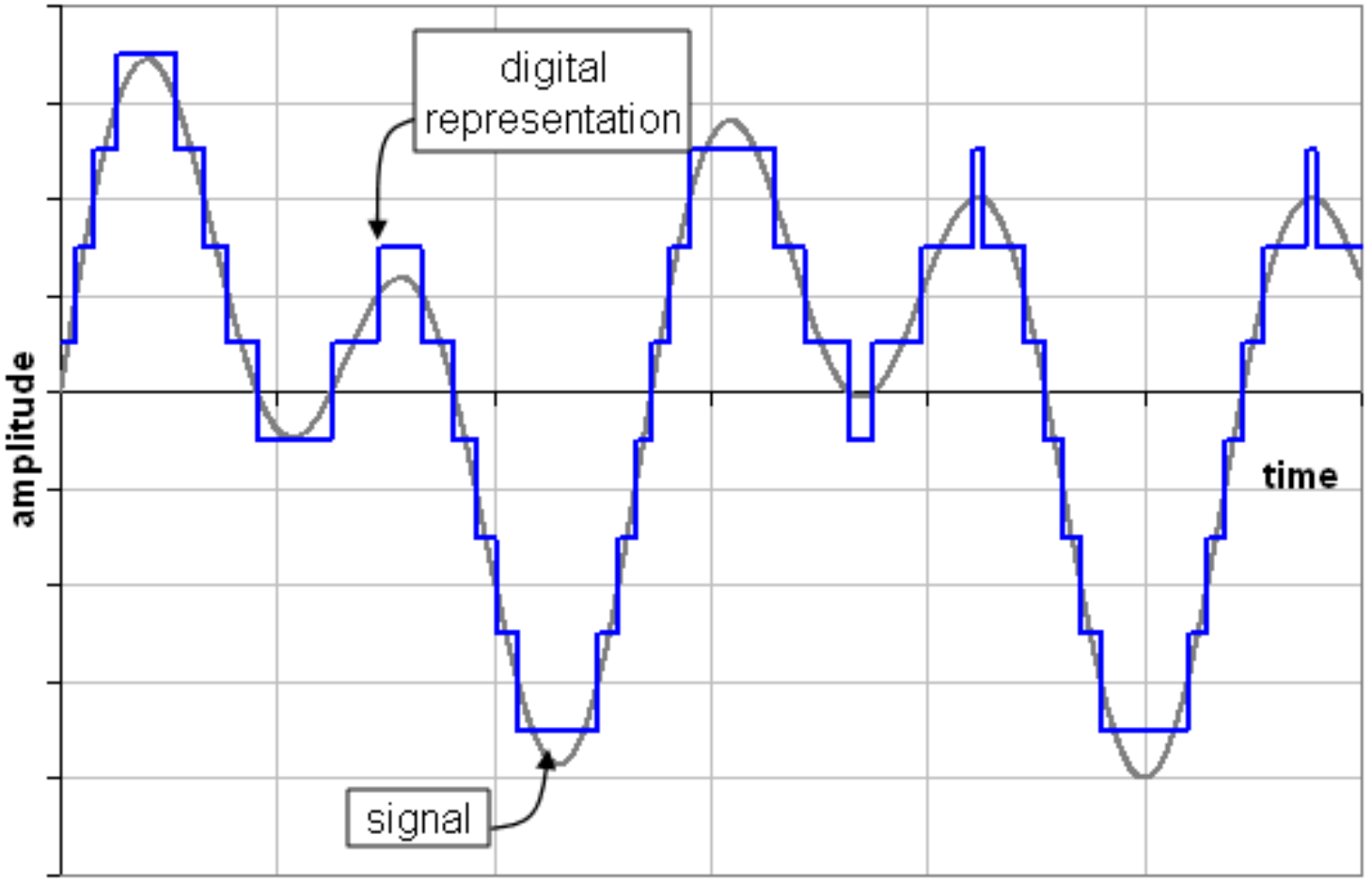
Digital Camera



0.5020	0.4941	0.4902	0.4078	0.4824	0.3608	0.2941	0.3686	0.5451	0.6431	0.4431	0.1412	0.1294	0.1255	0.1373	0.1412	0.1255	0.1176	0.1216	0.1333	0.1333
0.5020	0.4980	0.4863	0.3059	0.4510	0.3922	0.2706	0.2863	0.4745	0.5137	0.2078	0.1176	0.1098	0.1137	0.1294	0.1373	0.1294	0.1255	0.1255	0.1451	0.1412
0.5020	0.4941	0.4784	0.2392	0.3137	0.3569	0.3804	0.3451	0.3490	0.3255	0.1373	0.1451	0.1373	0.1333	0.1373	0.1373	0.1333	0.1294	0.1294	0.1529	0.1412
0.5020	0.4902	0.4627	0.2863	0.2314	0.2902	0.4392	0.4235	0.2902	0.2392	0.2078	0.1882	0.1765	0.1608	0.1451	0.1451	0.1451	0.1451	0.1412	0.1412	0.1333
0.5059	0.4784	0.4353	0.3804	0.2902	0.2627	0.3451	0.3647	0.2549	0.1804	0.1922	0.1922	0.1882	0.1725	0.1529	0.1529	0.1647	0.1647	0.1569	0.1176	0.1216
0.5098	0.4706	0.4118	0.3922	0.4196	0.3608	0.2784	0.2784	0.2353	0.1373	0.1333	0.1647	0.1725	0.1686	0.1569	0.1608	0.1686	0.1647	0.1490	0.1059	0.1333
0.5098	0.4627	0.3961	0.3333	0.5137	0.5020	0.3255	0.2863	0.2627	0.1608	0.1569	0.1451	0.1569	0.1647	0.1569	0.1608	0.1647	0.1490	0.1255	0.1059	0.1529
0.5255	0.4588	0.5255	0.3843	0.3725	0.3765	0.3098	0.2667	0.2627	0.2078	0.1961	0.1725	0.1647	0.1608	0.1686	0.1686	0.1490	0.1098	0.0784	0.1216	0.1451
0.5725	0.5529	0.5922	0.3373	0.3020	0.2863	0.2235	0.1961	0.2078	0.1804	0.1922	0.2039	0.2196	0.2196	0.1961	0.1608	0.1333	0.1333	0.1412	0.1647	0.1294
0.6157	0.6431	0.6000	0.2941	0.2627	0.2745	0.2471	0.2314	0.2235	0.1804	0.1882	0.1765	0.1843	0.1804	0.1490	0.1176	0.1059	0.1255	0.1490	0.1647	0.1686
0.6392	0.6745	0.4902	0.2588	0.2275	0.2588	0.2588	0.2588	0.2549	0.2118	0.2353	0.2157	0.1961	0.1686	0.1569	0.1529	0.1569	0.1529	0.1490	0.1647	0.2471
0.6706	0.6510	0.3412	0.2157	0.1725	0.1804	0.1569	0.1608	0.1922	0.2000	0.2471	0.2118	0.2000	0.1882	0.1804	0.1765	0.1686	0.1569	0.1490	0.2314	0.3098
0.6980	0.5765	0.2392	0.1882	0.1765	0.1882	0.1333	0.1059	0.1255	0.1176	0.1490	0.1137	0.1451	0.1725	0.1686	0.1451	0.1412	0.1725	0.2039	0.3020	0.3804
0.6941	0.4510	0.1922	0.1647	0.2039	0.2431	0.1725	0.1176	0.1255	0.0902	0.0863	0.1176	0.1490	0.1765	0.1804	0.1725	0.1961	0.2549	0.3059	0.3647	0.4431
0.6627	0.3373	0.1686	0.1373	0.1882	0.2314	0.1451	0.0980	0.1412	0.1373	0.1451	0.1922	0.1804	0.1647	0.1608	0.1843	0.2235	0.2706	0.3020	0.4314	0.4588
0.5176	0.2039	0.1098	0.1373	0.2471	0.1608	0.1176	0.1451	0.1412	0.0392	0.2157	0.1608	0.1451	0.1529	0.1804	0.2000	0.2235	0.2824	0.3412	0.3686	0.4863
0.4314	0.2235	0.1765	0.1843	0.1529	0.1294	0.2000	0.0941	0.0784	0.1922	0.0902	0.1490	0.1333	0.1451	0.1804	0.2157	0.2431	0.3020	0.3608	0.4588	0.5451
0.7647	0.8157	0.8745	0.7216	0.4196	0.1137	0.0941	0.1529	0.1255	0.1333	0.0863	0.1333	0.1216	0.1373	0.1882	0.2314	0.2706	0.3294	0.3882	0.5020	0.5725
0.8627	0.8863	0.8588	0.9255	0.8902	0.6118	0.1255	0.0157	0.1608	0.0784	0.1412	0.1255	0.1176	0.1373	0.1922	0.2431	0.2863	0.3490	0.4078	0.4980	0.5725
0.9137	0.9059	0.8431	0.8353	0.8824	0.9255	0.5922	0.0510	0.0784	0.1059	0.1176	0.1216	0.1216	0.1451	0.1961	0.2392	0.2824	0.3529	0.4196	0.5216	0.6000
0.8627	0.8863	0.8745	0.8902	0.7843	0.8118	0.9255	0.4118	0.0275	0.1020	0.1059	0.1176	0.1255	0.1529	0.1961	0.2275	0.2667	0.3490	0.4275	0.5490	0.6235

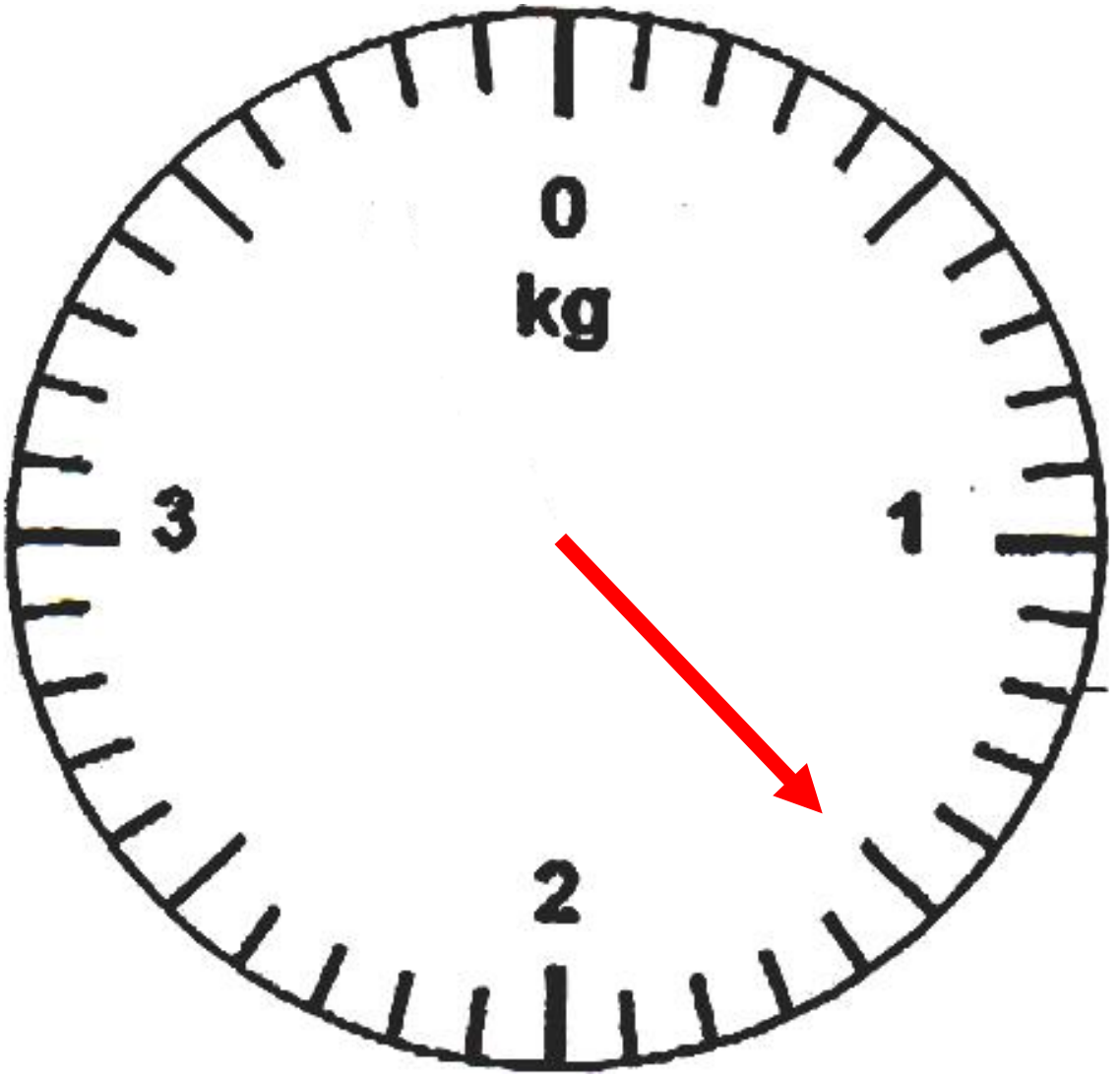


Analog to Digital Converter



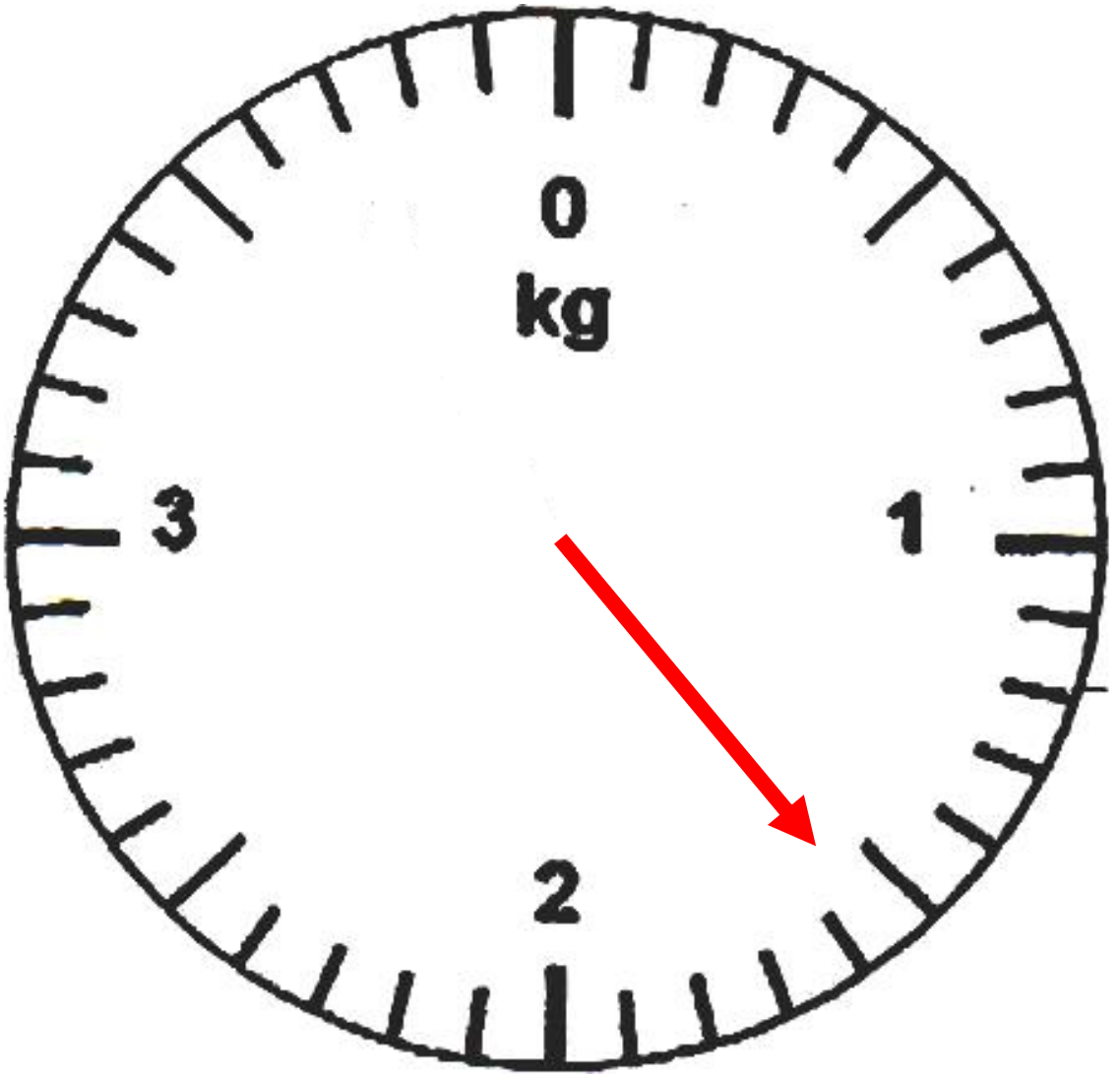
Signal Quantization

Quantization



1.5 kg

Quantization



1.5 kg

Quantization

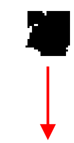
$$v = \left\lfloor \frac{v_i}{v_{ref}} \times 2^{bits} - 1 \right\rfloor$$

v = output

v_i= input

v_{max}= maximum input range

$bits$ = number of bit



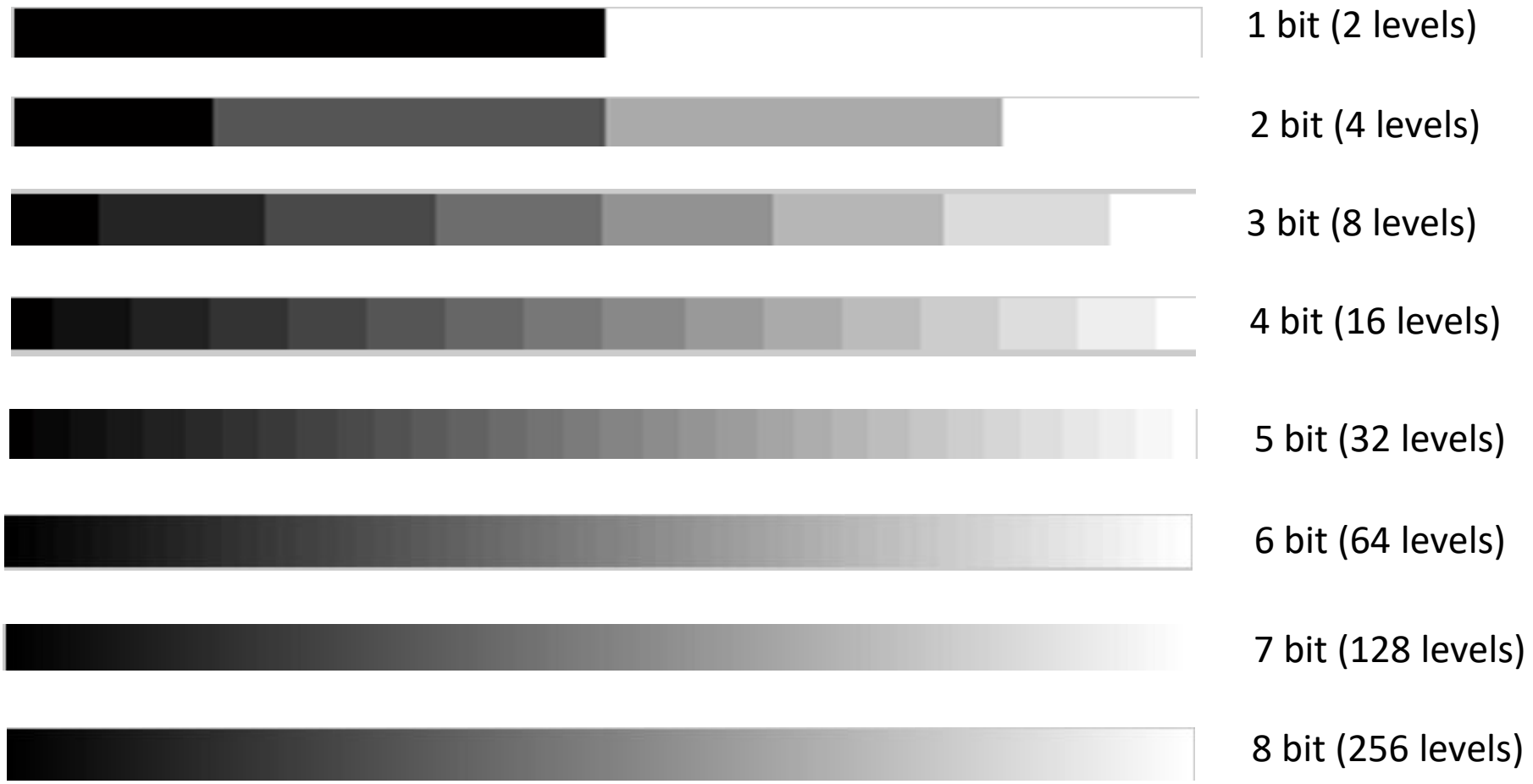
1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Bits=1

2 levels

Binary image

Image Quantization



More bits = More shade

Image Quantization

1 bit (2 levels)

2 bit (4 levels)

3 bit (8 levels)

4 bit (16 levels)

5 bit (32 levels)

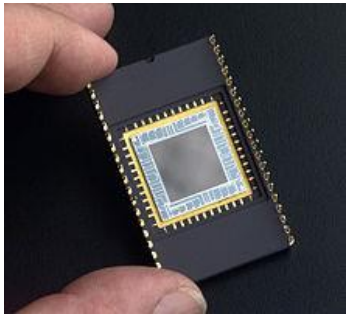
6 bit (64 levels)

7 bit (128 levels)

8 bit (256 levels)

More bits = More shade

Question !



A Pixel from CCD chip have a measure value of 2 volts, this CCD has a maximum range of 5 volts.
What is the value of this pixel when it was quantize into 12 bits

v = ?
v_i= 2 volts
v_{max}= 5
$bits$ = 12

$$v = \left\lfloor \frac{2}{5} \times 2^{12} - 1 \right\rfloor$$

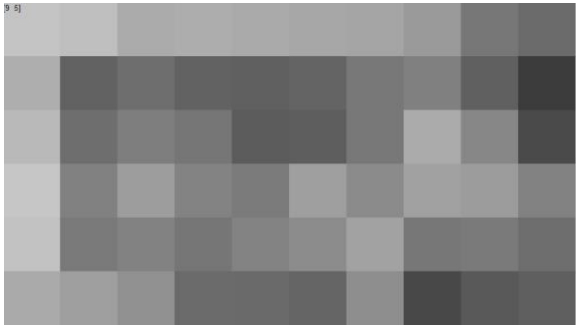
= 1637

= 665H

=11001100101B

Image Sampling

1 x 1



9 x 5

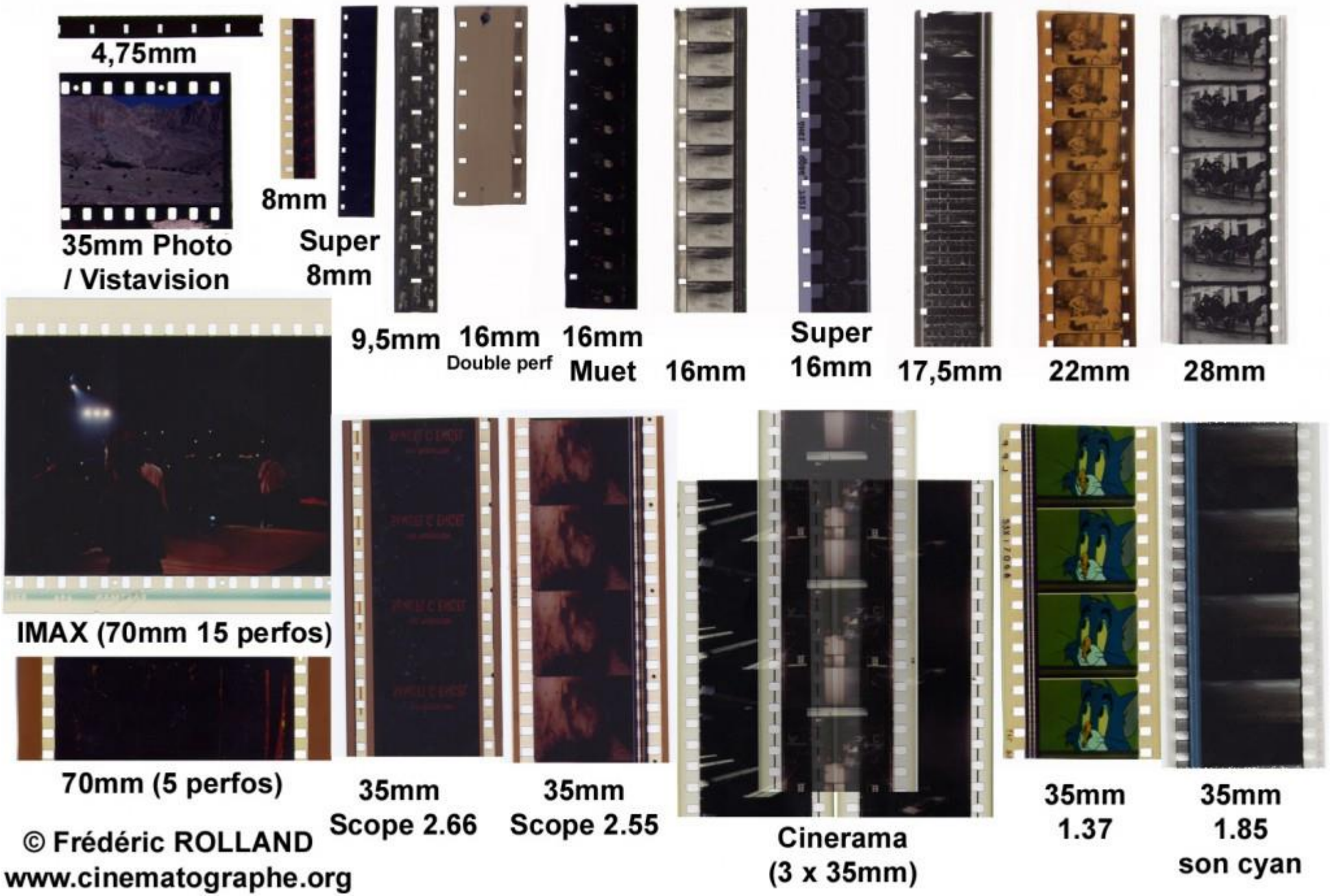
48 x 27

96 x 54

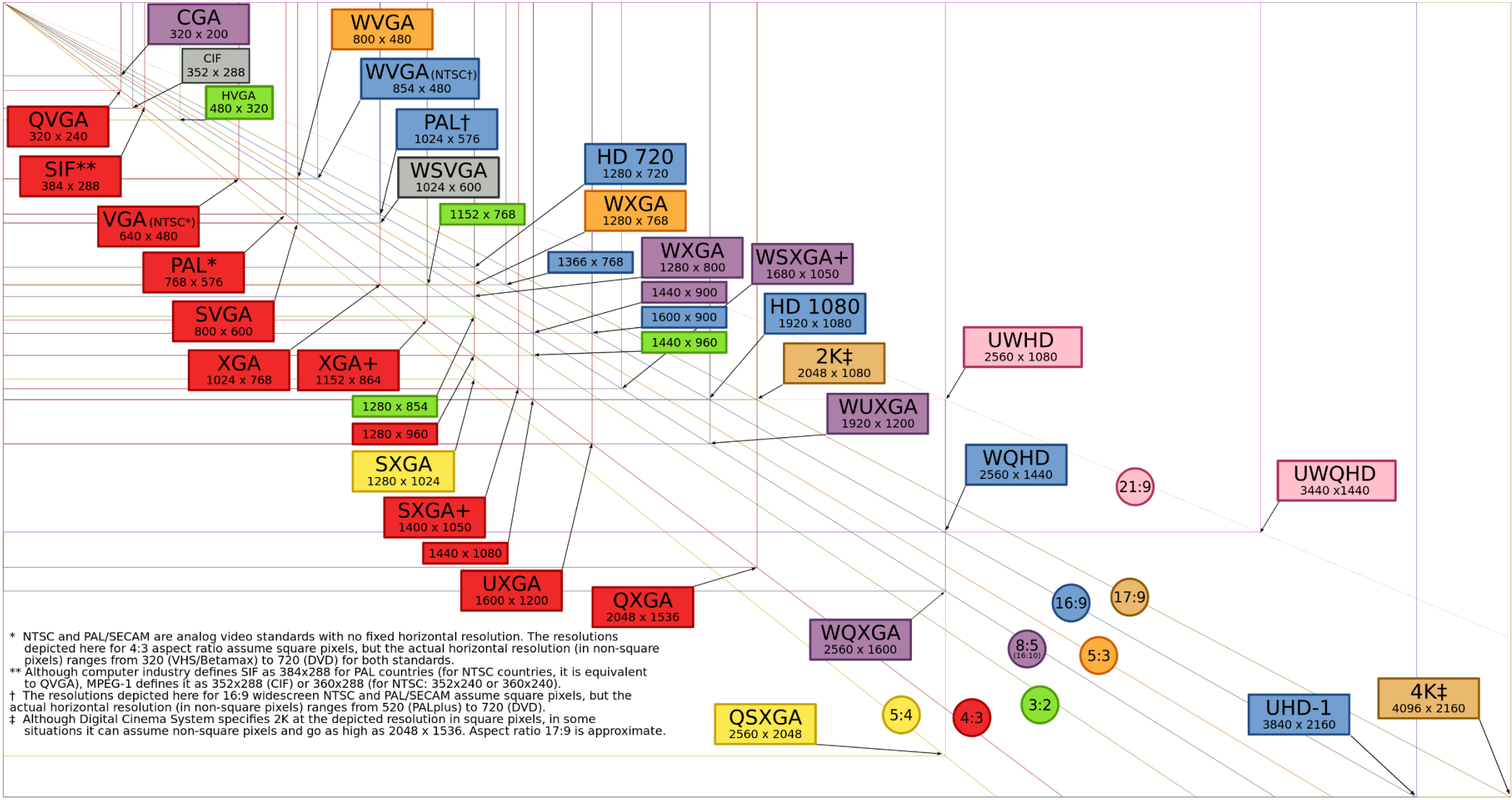
192 x 108

864 x 486

RESOLUTION OF PHOTOCHEMICAL FORMAT



RESOLUTION OF DIGITAL PHOTO FORMAT



* NTSC and PAL/SECAM are analog video standards with no fixed horizontal resolution. The resolutions depicted here for 4:3 aspect ratio assume square pixels, but the actual horizontal resolution (in non-square pixels) ranges from 320 (VHS/Betamax) to 720 (DVD) for both standards.

** Although computer industry defines SIF as 384x288 for PAL countries (for NTSC countries, it is equivalent to QVGA), MPEG-1 defines it as 352x288 (CIF) or 360x288 (for NTSC: 352x240 or 360x240).

† The resolutions depicted here for 16:9 widescreen NTSC and PAL/SECAM assume square pixels, but the actual horizontal resolution (in non-square pixels) ranges from 520 (PALplus) to 720 (DVD).

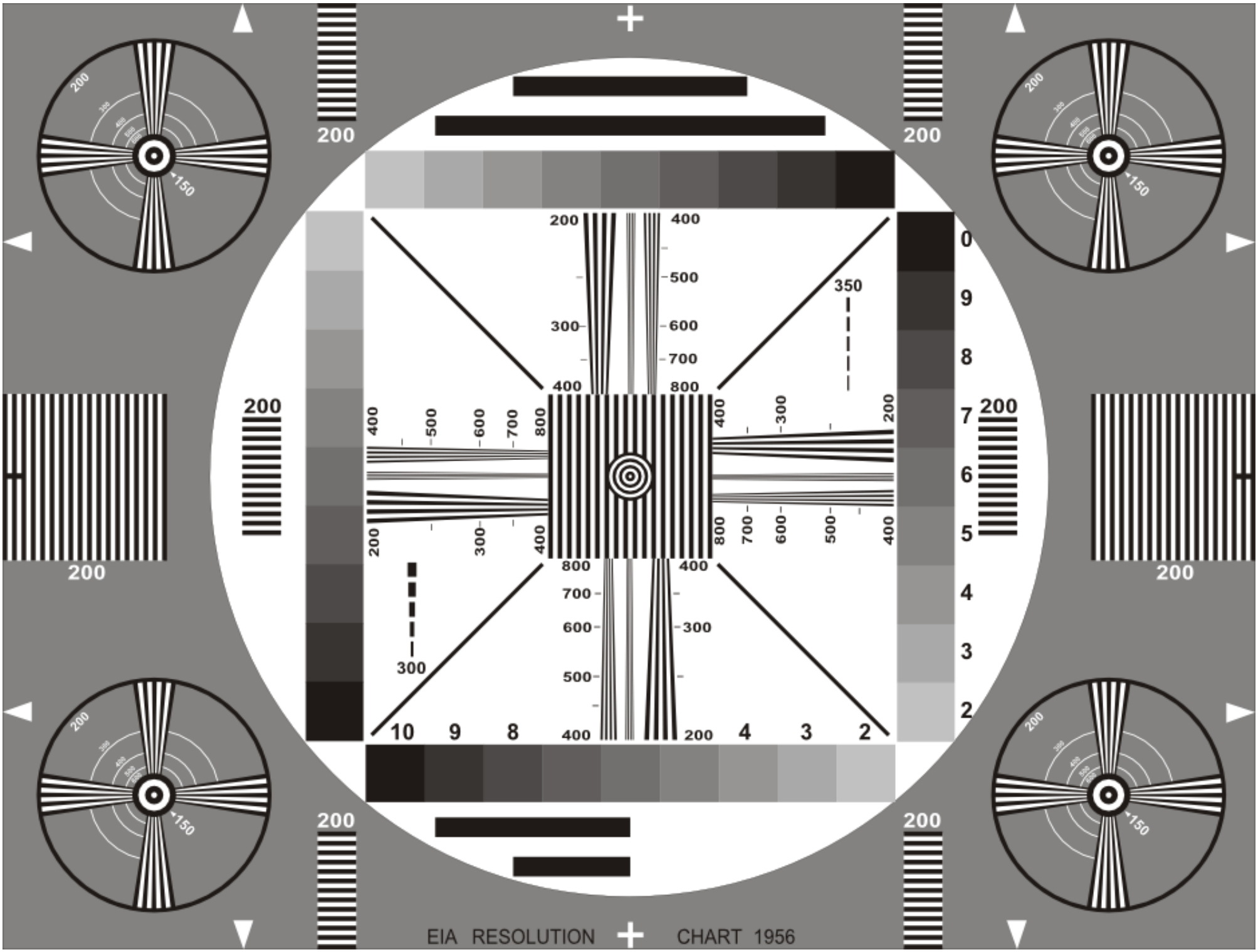
‡ Although Digital Cinema System specifies 2K at the depicted resolution in square pixels, in some situations it can assume non-square pixels and go as high as 2048 x 1536. Aspect ratio 17:9 is approximate.

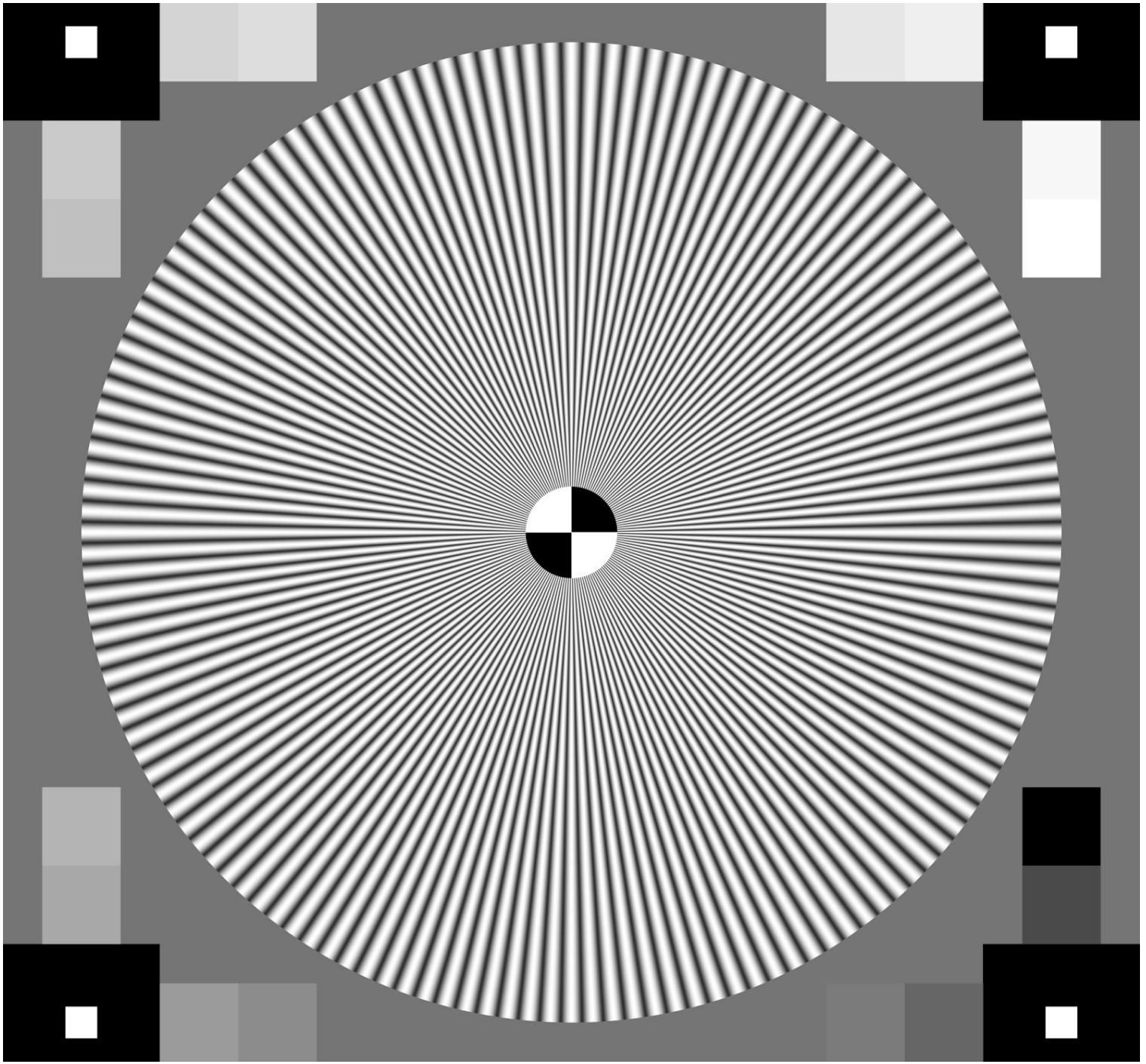
RESOLUTION CHART

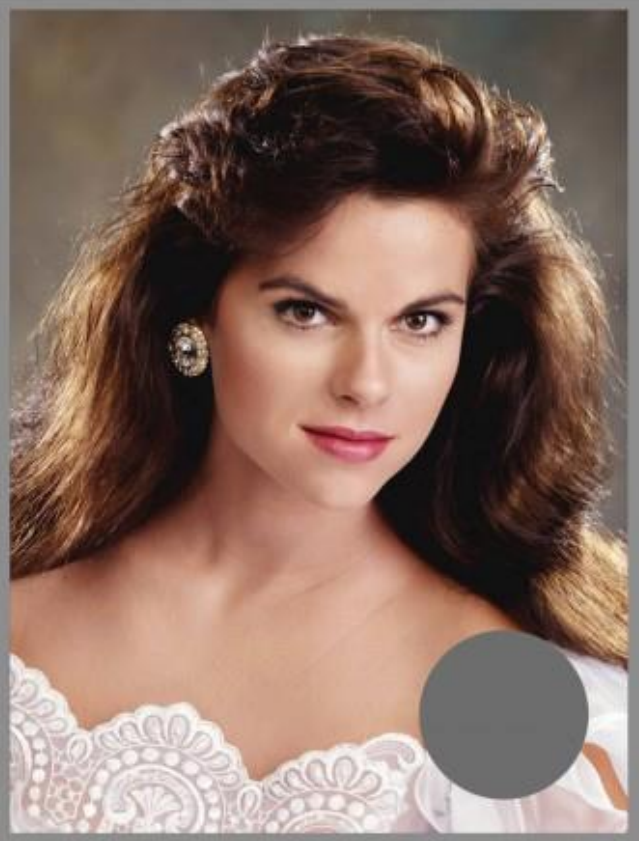
RESOLUTION TEST PATTERN

QUALITY SERVICE

FUJIFILM
I&I – Imaging & Information


200
200
200
200
200
200
200
200
200
200
200
200
150
150
150
150
350
300
300
0
9
8
7
6
5
4
3
2
10
9
8
4
3
2
EIA RESOLUTION CHART 1956





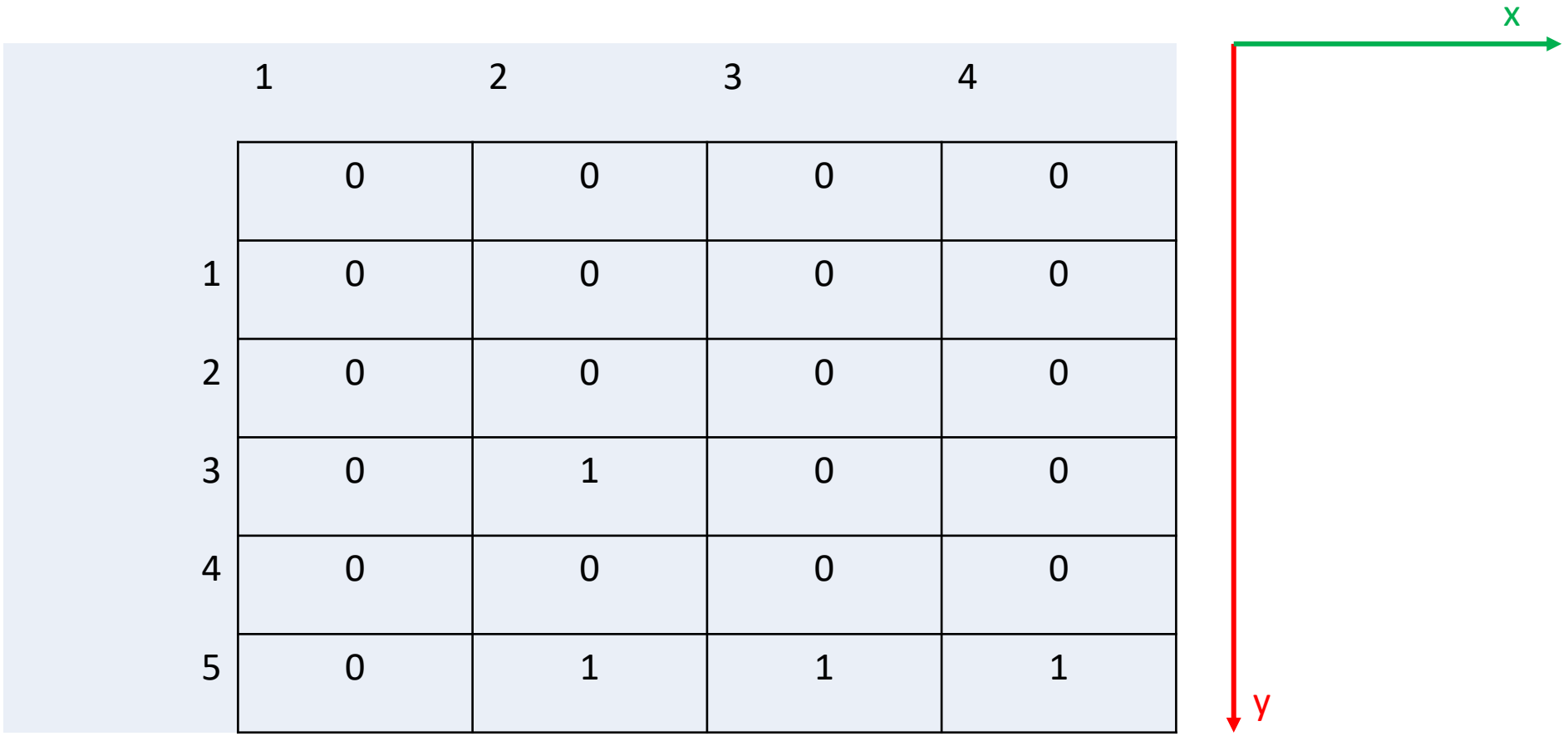
Times Roman 14 Point
Times Roman 12 Point
Times Roman 8 Point
Times Roman 6 Point

Helvetica 14 Point
Helvetica 12 Point
Helvetica 8 Point
Helvetica 6 Point

255
242
229
216
204
191
178
165
153
140
127
114
102
89
76
63
51
38
25
12
0

Macbeth ColorChecker™ Color Rendition Chart

Spatial Coordinate System



Bitmap **G**

G(2,3)=1

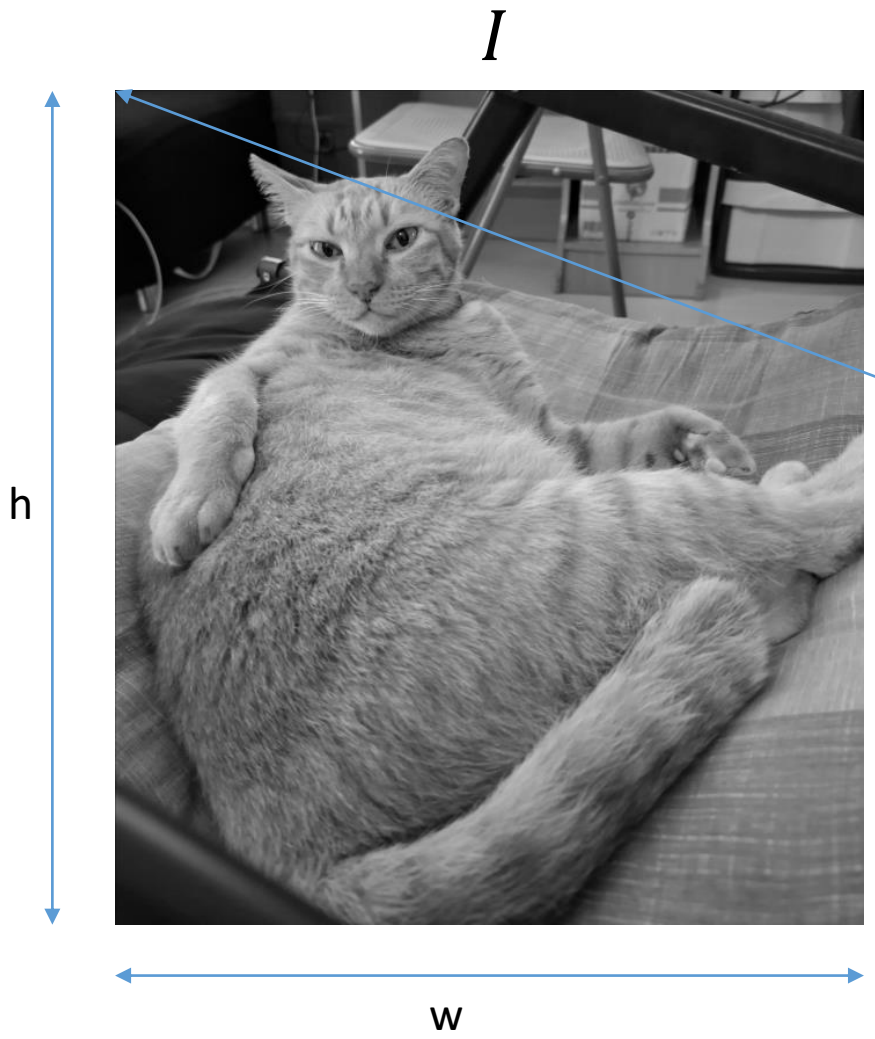
x=2,y=2

G(x,y)=0

X={2,3,4} , **Y**={5,5,5}

G(**X**,**Y**)={1 ,1 ,1}

Spatial Coordinate System



$$I_{(0,0)} = \ ?$$

I[0,0] = 0

Spatial Coordinate System

I

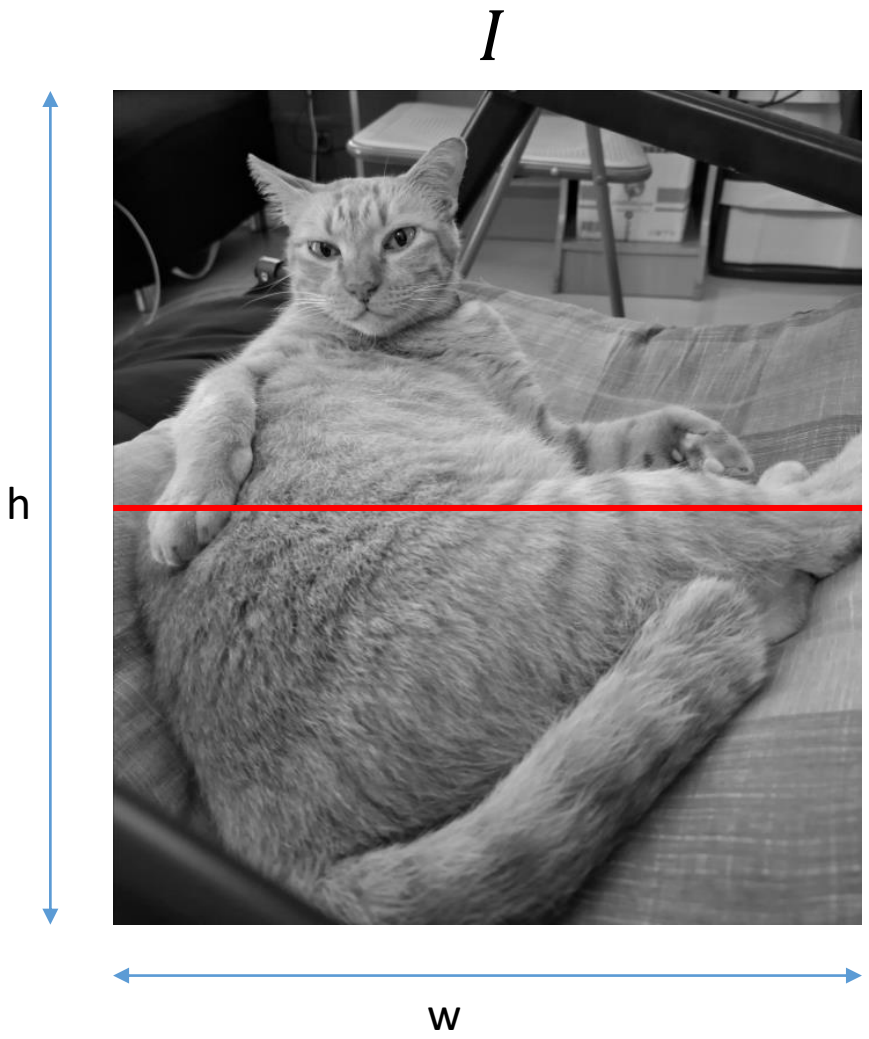
h

w

$I_{(\frac{w}{2},\frac{h}{2})} = ?$

I[w/2,h/2] = 140

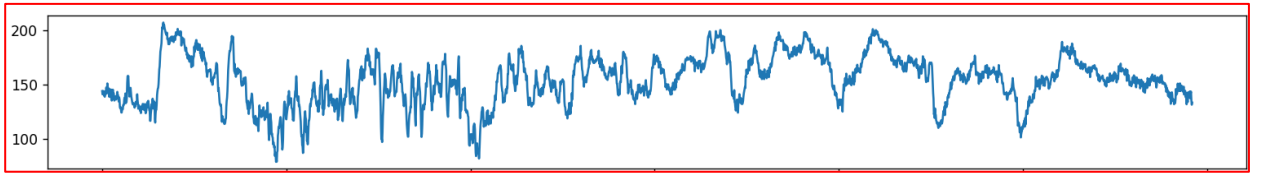
Spatial Coordinate System



$$W = 0..w$$

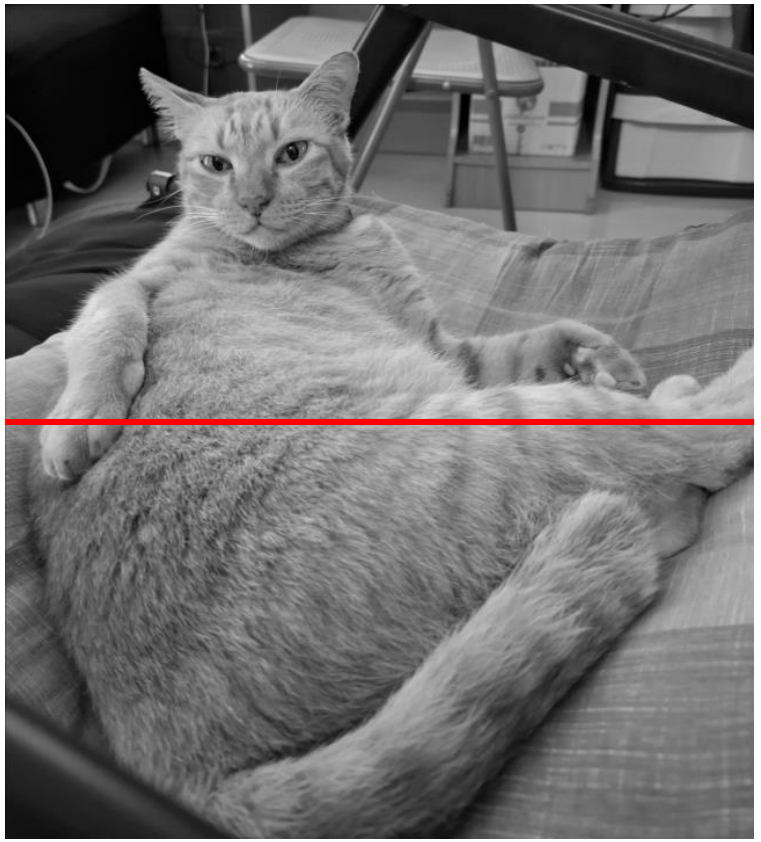
$$W = \{0,1,2,3,4, \ldots\ldots, w\}$$

$$I_{(W,\frac{h}{2})} = \ ?$$

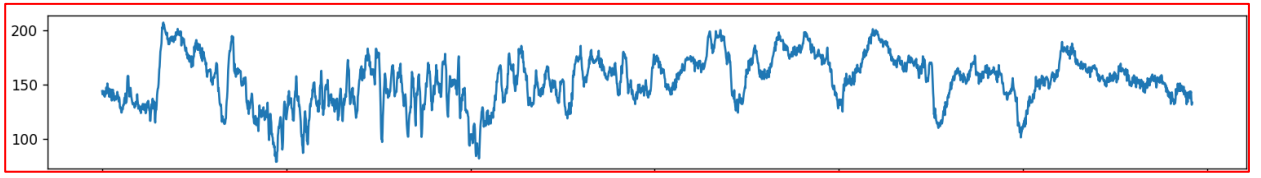


Spatial Coordinate System

I

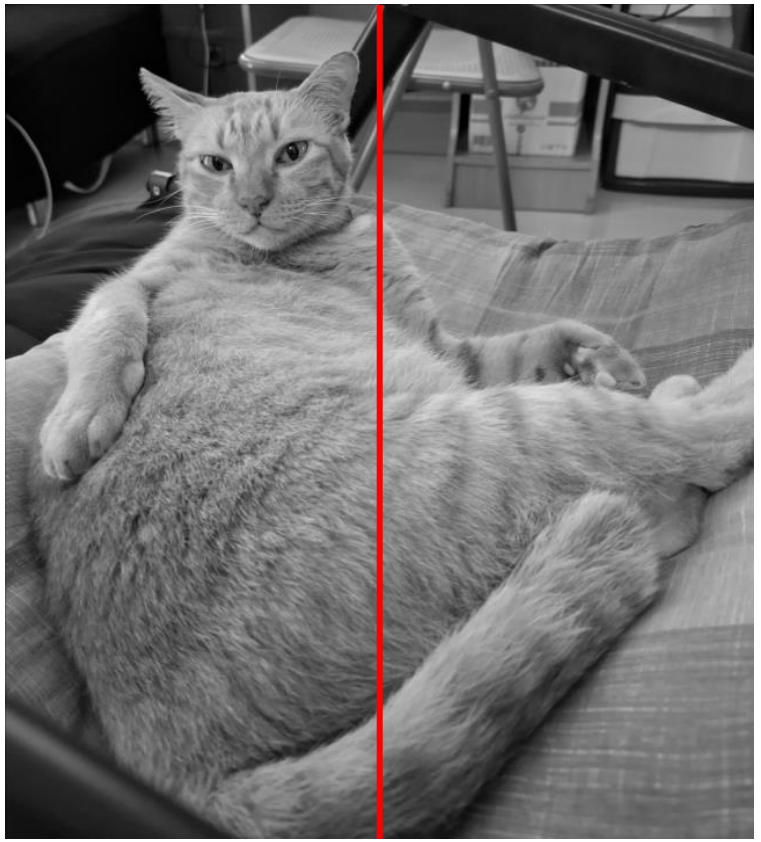


$$I_{(:,\frac{h}{2})} = ?$$



Spatial Coordinate System

I



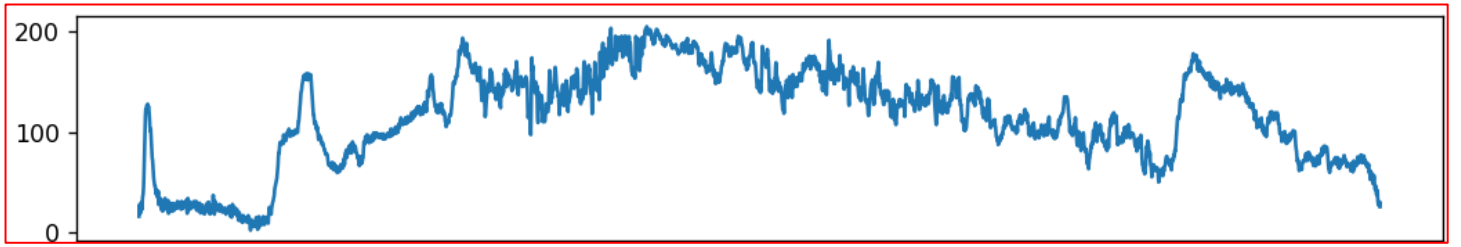
h

w

$$H = 0..h$$

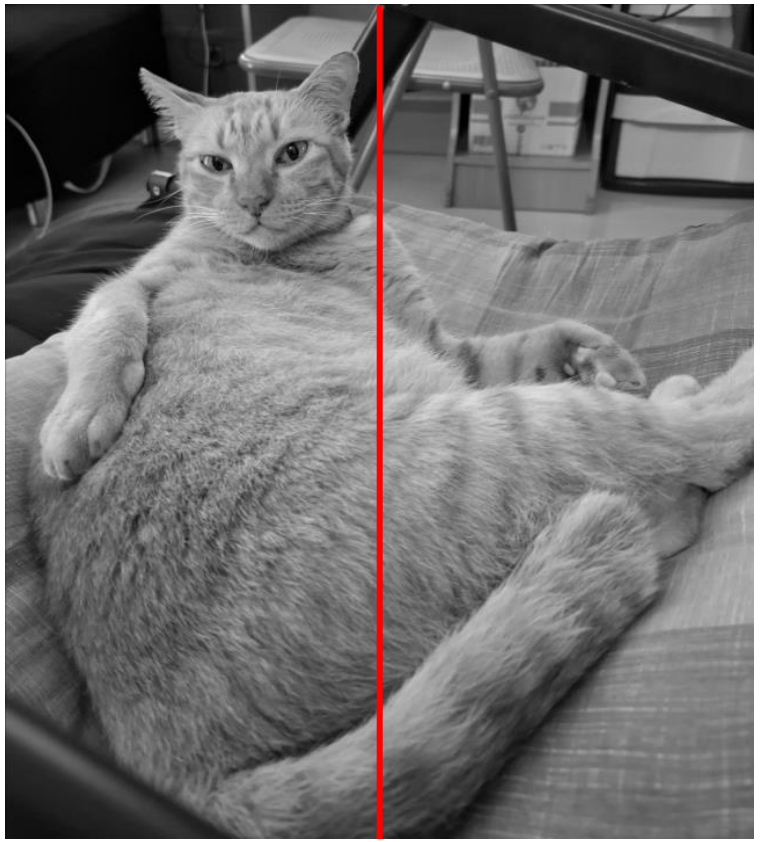
$$H = \{0,1,2,3,4, \ldots\ldots, h\}$$

$$I_{(\frac{w}{2},H)} = \ ?$$



Spatial Coordinate System

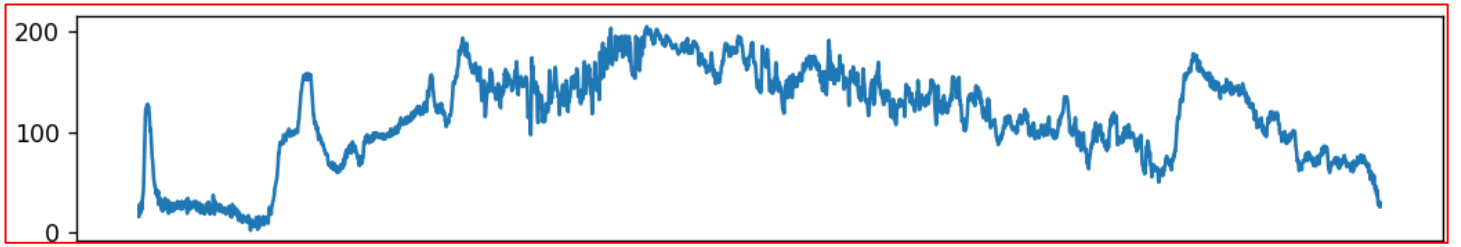
I



h

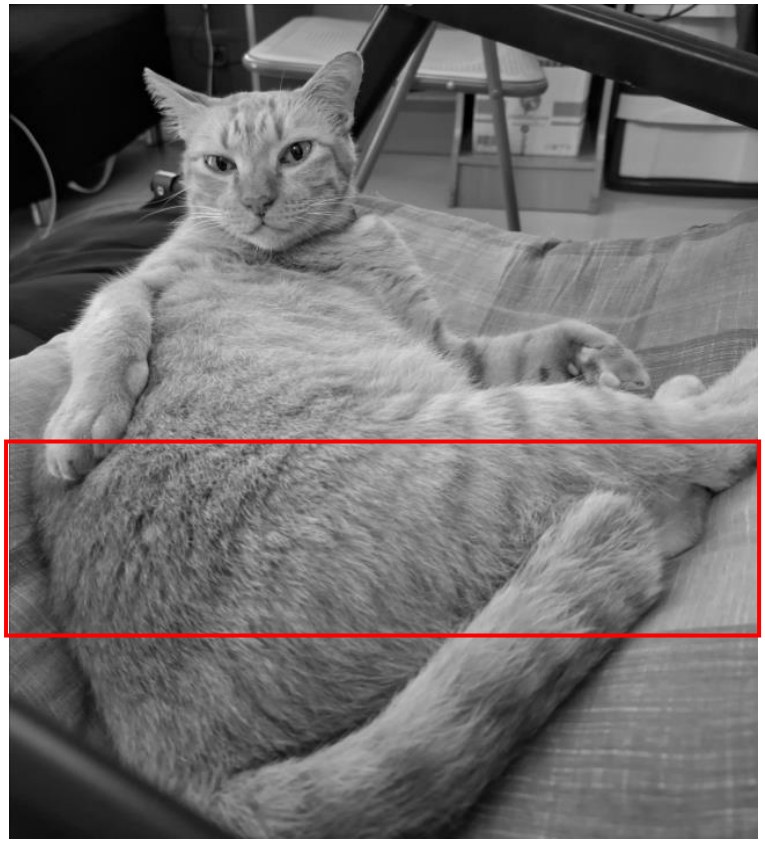
w

$$I_{(\frac{w}{2},:)} = ?$$

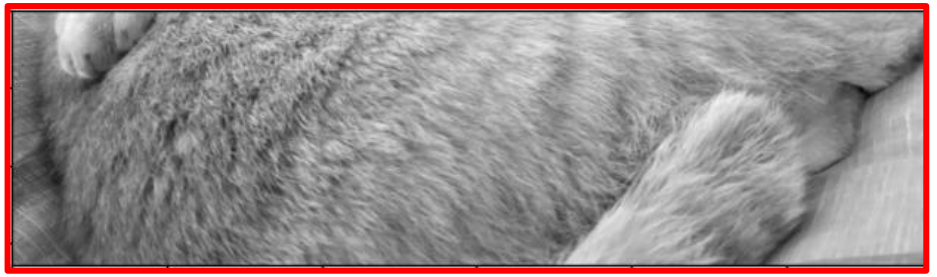


Spatial Coordinate System

I

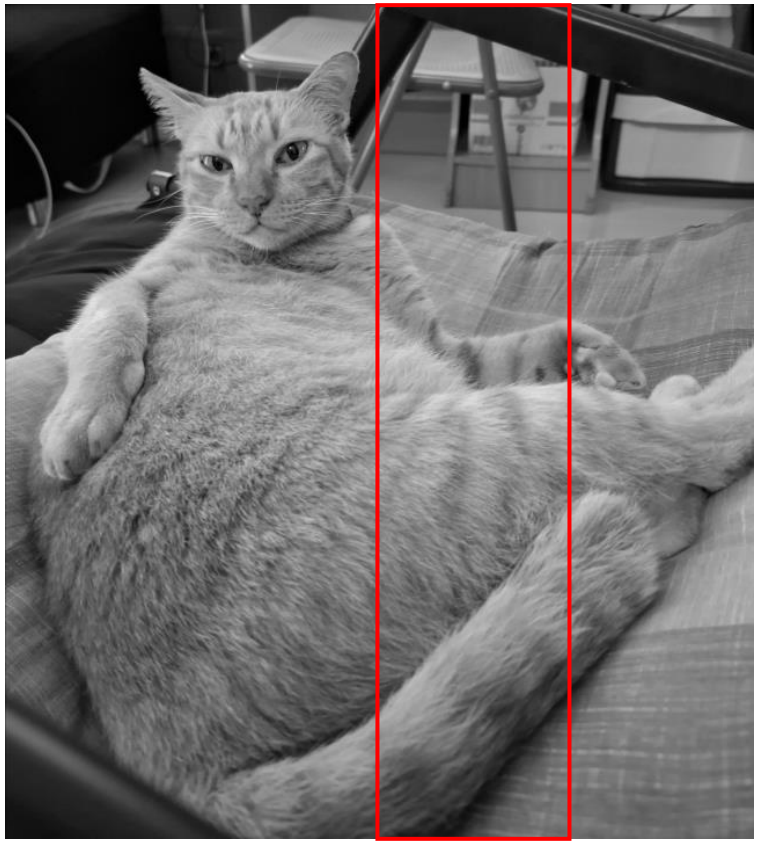


$$I_{(:,\frac{h}{2}\cdots\frac{3h}{4})} = ?$$



Spatial Coordinate System

I

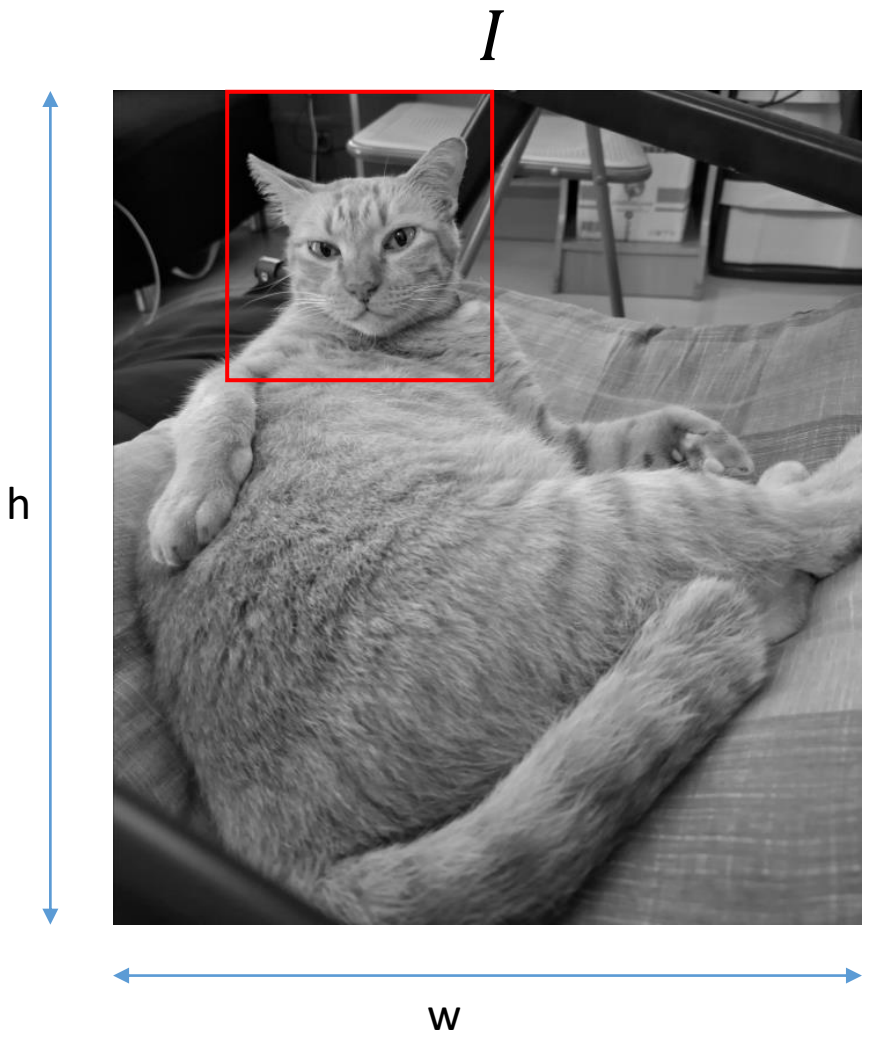


h

w

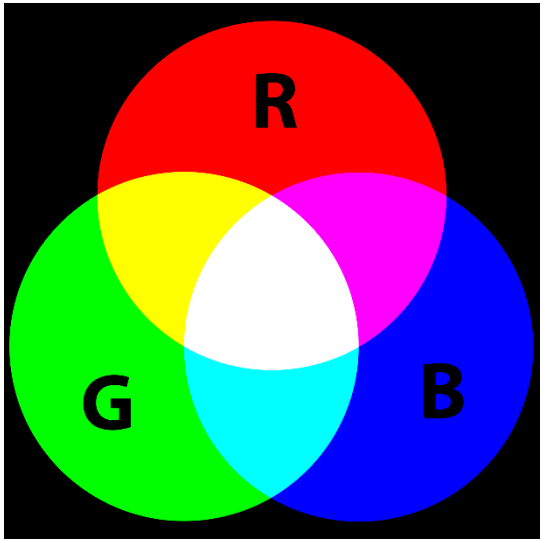
$$I_{\left(\frac{w}{2}\ldots\frac{3w}{4},:\right)} = ?$$

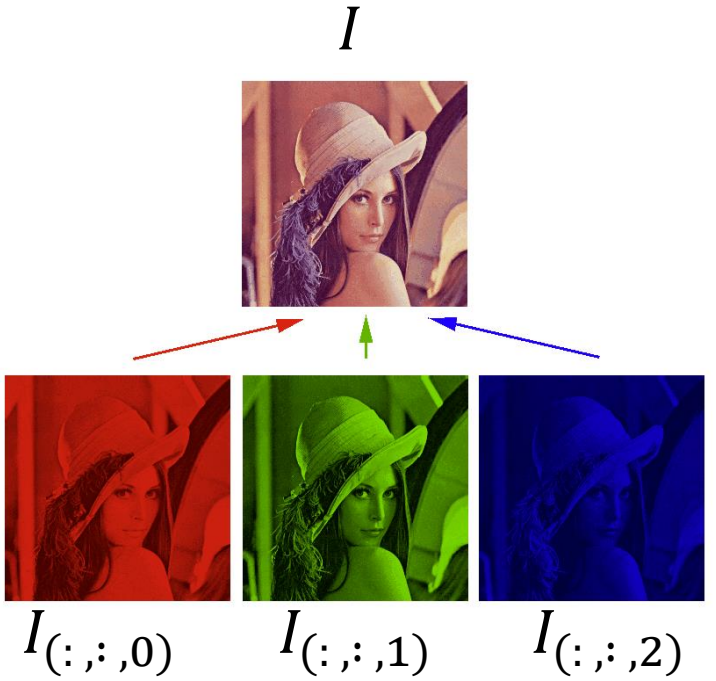
Spatial Coordinate System

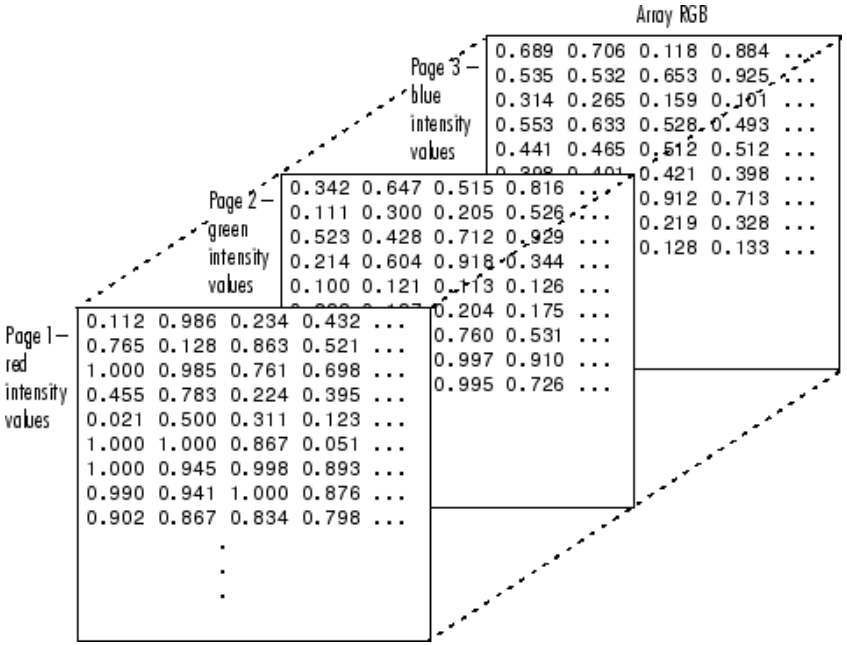


$$I_{\left(\frac{w}{6}\ldots\frac{w}{2},0..\frac{w}{6}\right)} = ?$$

RGB Color plane







RGB color format

24-BIT RGB (True color)

Sample Length:	8								8								8							
Channel Membership:	**Red**								**Green**								**Blue**							
Bit Number:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Memory Usage

24-BIT RGB (True color)

$$bytes = \frac{\sum_{i=1}^{d}(h \times w) \times bits_i}{8}$$

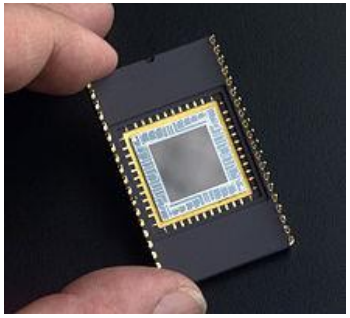
$$bytes = \frac{(h \times w) \times 8 + (h \times w) \times 8 + (h \times w) \times 8}{8} = \frac{h \times w \times 24}{8}$$

RGB color format

16-BIT RGB (High color)

Sample Length:	5					6						5				
Channel Membership:	**Red**					**Green**						**Blue**				
Bit Number:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RGBAX	R. G. B. A. X															
Sample Length Notation:	**5.6.5.0.0**															

Question !



You need to load a 16-bit RGB Bitmap image with resolution of 1080 x 720 Pixels into the memory

Q1: Calculate the memory requirement for the whole image

Q2: Calculate the memory requirement only for the green plane

$$w = 1080, h = 720, d_1 = 5, d_2 = 6, d_3 = 5$$

Sol(1) $$bytes = \frac{1080 \times 720 \times 16}{8} = 1.55520MB$$

Sol(2) $$bytes = \frac{1080 \times 720 \times 6}{8} = 583{,}200kB$$

Matlab & Python image processing function

Read image file:
im=imread('filename');
Display image:
imshow(**im**);
Get image dimension:
[*h w d*]=size(**im**);
Resize image:
im2=imresize(**im**,[*h w*]);
Color separation:
R=**im**(:,:,1);
G=**im**(:,:,2);
B=**im**(:,:,3);
RGB to Gray
im2=rgb2gray(**im**);

Read image file:
im=Image.open('filename')
Display image:
imshow(**im**)
show()
Get image dimension:
imrgb=array(im)
[h,w,d]=imrgb.shape
[*h w d*]=size(**im**);
Resize image:
im2=imresize(**im**,[*h ,w*]);
Color separation:
im_r=im_rgb[:,:,0]
im_g=im_rgb[:,:,1]
im_b=im_rgb[:,:,2]
RGB to Gray
im2=mahotas.colors.rgb2gray(**im_rgb**);

More RGB formula

https://en.wikipedia.org/wiki/List_of_monochrome_and_RGB_palettes

Assignment

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