



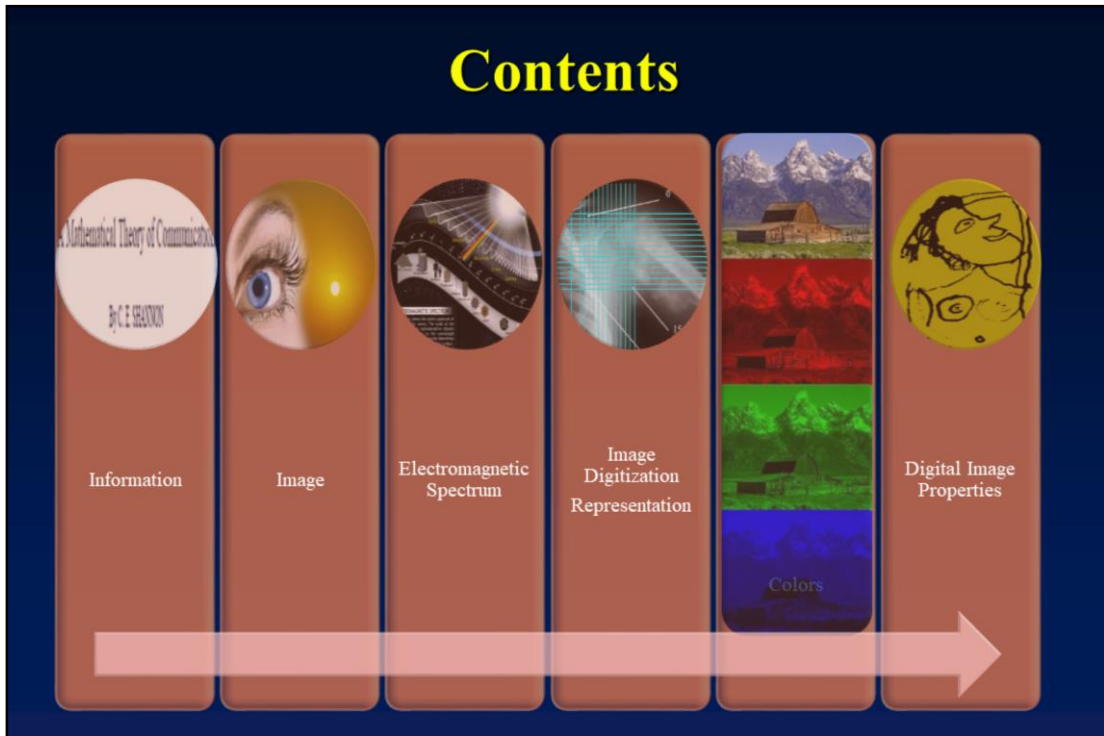
Medical digital imaging

Information, Digital images

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Contents



In this lecture we will discuss:

- information
- images,
- images from the different part of electromagnetic spectrum,
- basics of image digitization and representation
- including colors
- and image properties

**Are the following two disclosures
information for you?**

1



2

The color of the
lecturer's hair is
brown.

What is Information?

Information is **new knowledge**

- We can **perceive**
- We can **understand**
- We **need**



Increases our knowledge
Decreases our uncertainty



The basic unit of information is bit,
1 bit of information resolves 50% uncertainty.



Information is the fundamental concept of the informatics.

Diverse definition lives in everyday life, in which common is, that the information:

- reduces uncertainty
- carries new knowledge
- is needed

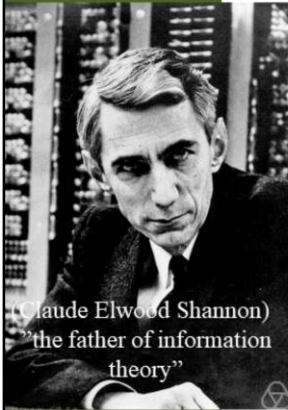
Information is what you get when your uncertainty about sg is reduced. When your uncertainty is decreased then you receive information.

The basic unit of information is bit, 1 bit of information resolves 50% uncertainty.

When you flip a fair coin you are uncertain whether it lands on head or tail. When it lands you can see what side it landed, your uncertainty is gone, the side of the coin landed gives information.

Foundation of information theory

Reprinted with corrections from *The Bell System Technical Journal*,
Vol. 27, pp. 379–423, 623–656 (July, October, 1948).



Claude Elwood Shannon
"the father of information
theory"

A Mathematical Theory of Communication

By C. E. SHANNON

INTRODUCTION

THE recent development of various methods of modulation such as frequency modulation and spread spectrum bandwidth for signal-to-noise ratio has intensified the interest in information theory. The basis for such a theory is contained in the important papers of Nyquist and Hartley. In the present paper we will extend the theory to include a number of new aspects of communication in the channel, and the savings possible due to the statistical structure of the final destination of the information.

The fundamental problem of communication is that of reproducing at one point exactly or approximately a message selected at another point. Frequently the messages to be transmitted are correlated according to some system with certain physical aspects of communication are irrelevant to the engineering problem. The message is one selected from a set of possible messages. The system of possible selection, not just the one which will actually be chosen since the number of messages in the set is finite then this number of possible choices can be regarded as a measure of the information produced when one choice is made. As was pointed out by Hartley the

Information

- formation,
- structure,
- management,
- storage,
- access,
- transmission

Claude E. Shannon's article, the foundation of information theory.

The information theory is a science area dealing with data that is understood as a new knowledge. It mainly deals with the formation, structure, management, storage, access and transmission of information.

Information theory also studies the different uses of information, information systems.

**Are the following two disclosures
information for you?**

1



2



They are not:

1: We can perceive but we can't understand.

2: We sense, understand, but it does not matter to us or it does not contain new knowledge.

Data

Data is the fixed information (with the help of signs) for storing and transmitting



The basic unit of data in computing is the bit (0/1)

The knowledge acquired will be stored in some way. We forget and die.

Data is the fixed information with the help of signs for storing and transmitting.

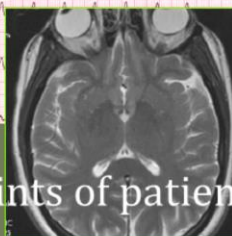
The basic unit of the data in computing is the bit. It is the amount of information stored by a digital device (data).

In information theory one bit is the uncertainty of a binary random variable that is 0 or 1 with equal probability (or the information that is gained when the value of such a variable becomes known).

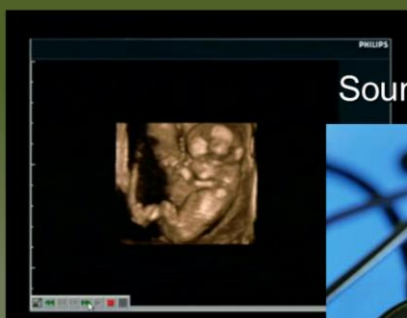
Basic type of information

In the health domain, according to the type of sign carrying the information:

- Numeric
Eg. 38,7 C⁰, 136/86 Hgmm
- Analogue
- **Image**
- Texts
reports, complaints of patient

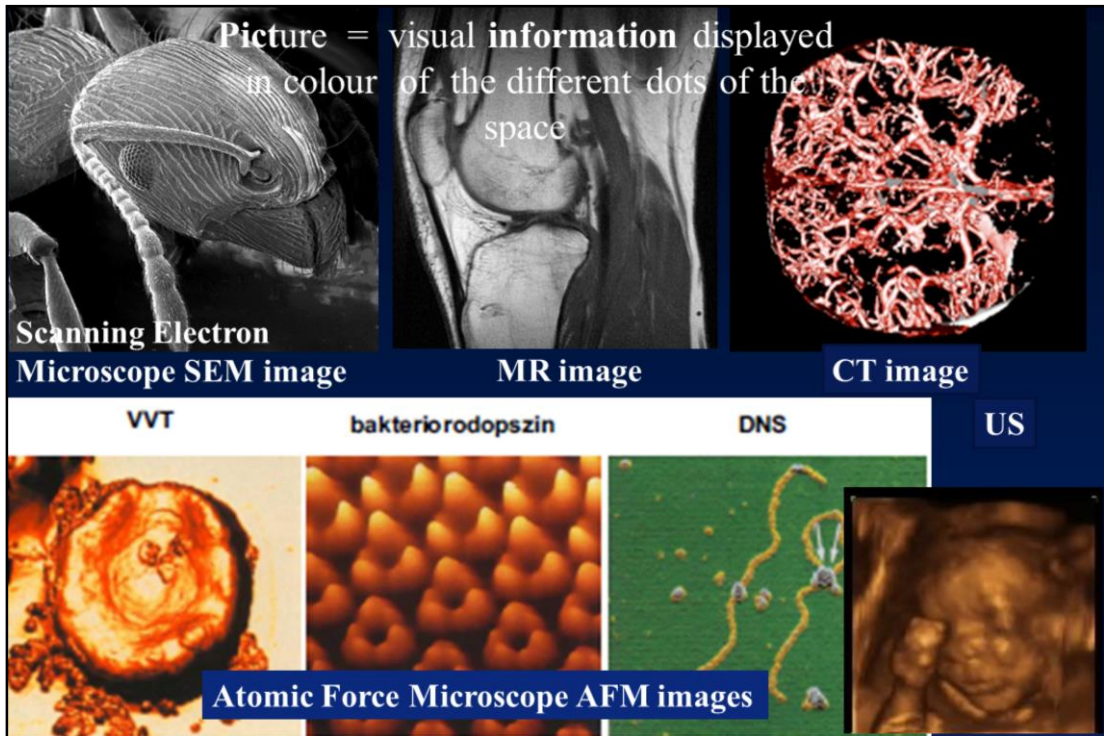


Video



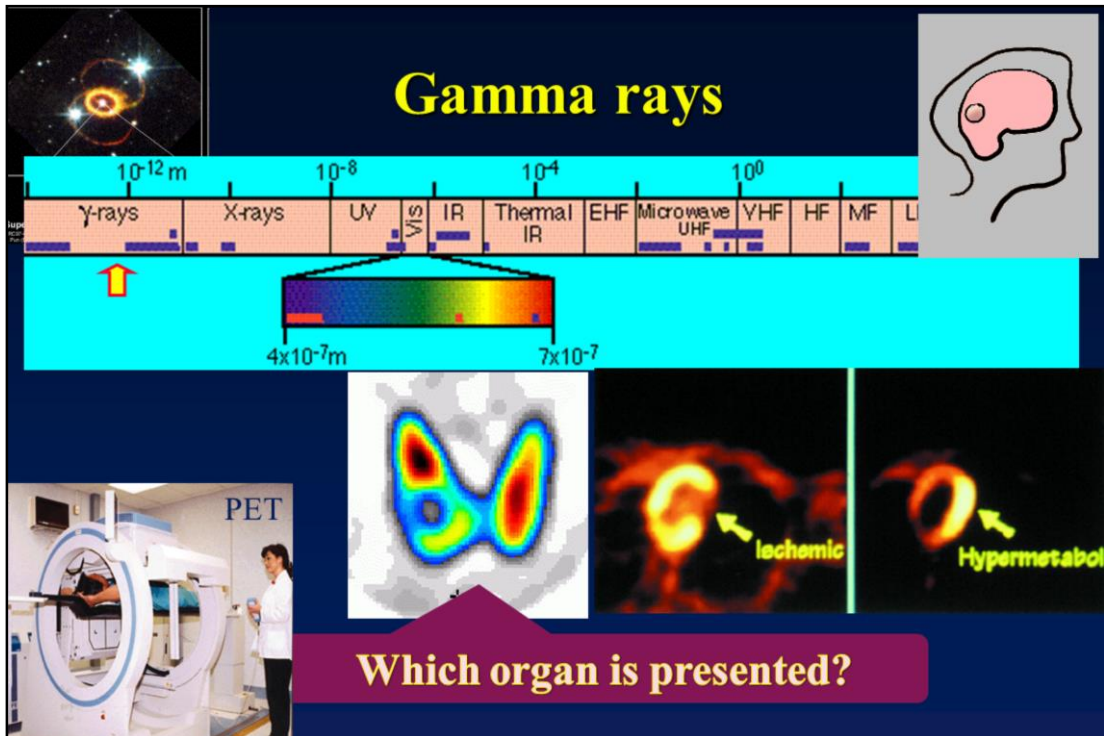
Sound





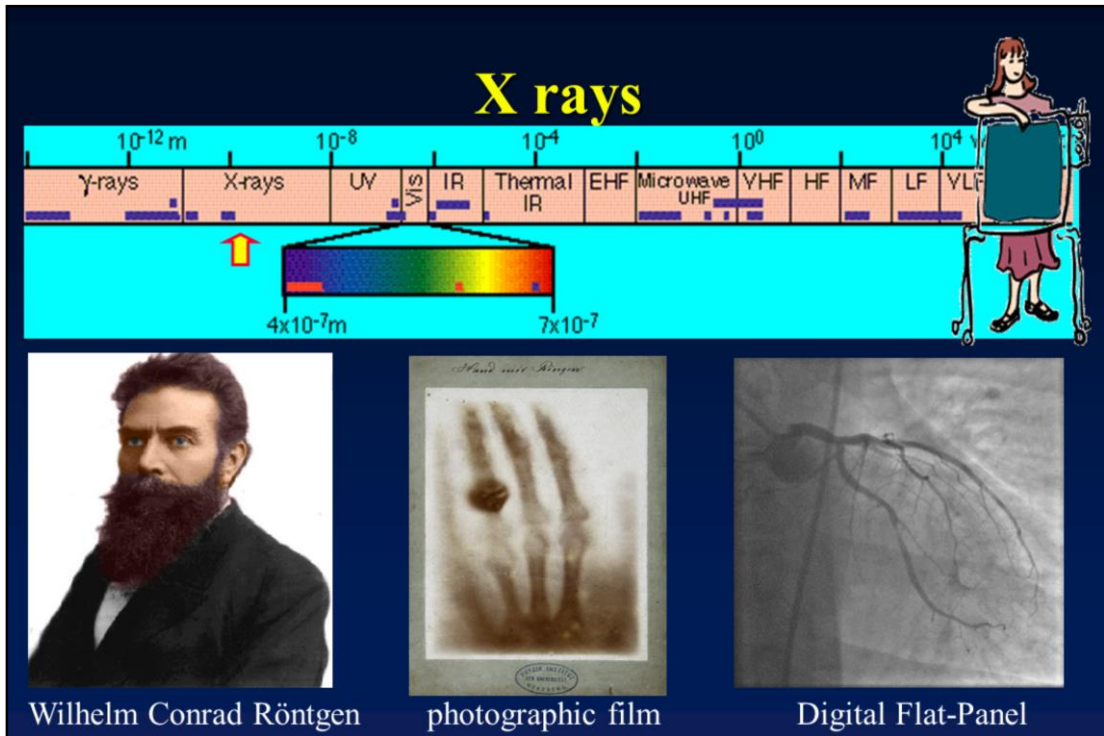
Picture is **visual information** displayed in colour or greyscale of the different dots of the space.

Here information means any signs which can be converted into electric potential (intensity, concentration, relaxation time, absorption, force, sound, etc.)



All of the electromagnetic radiation can be arranged by frequency (wavelength, energy) in this way we get the electromagnetic spectrum.

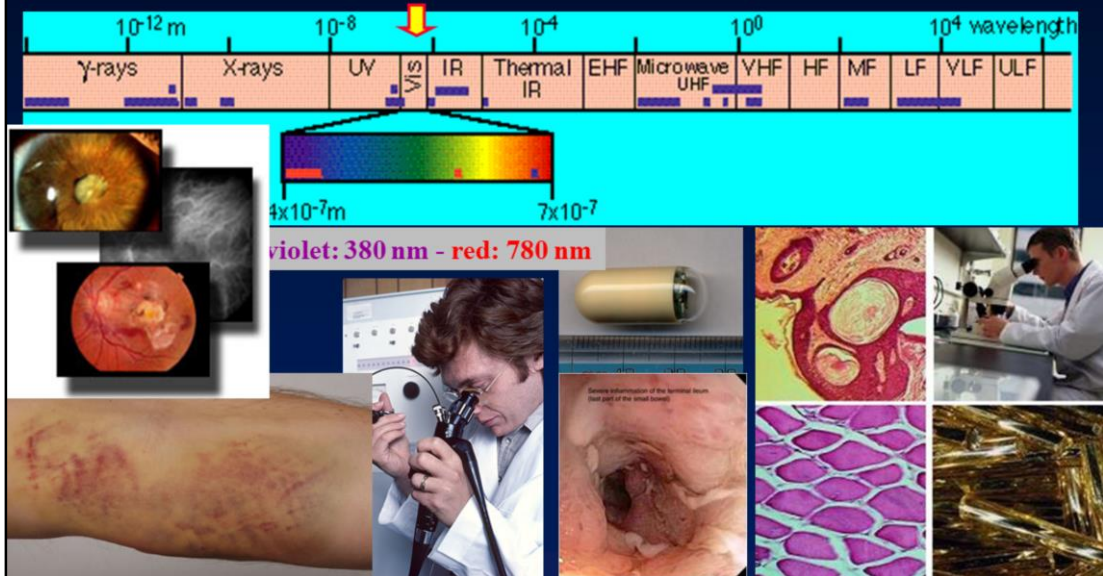
Gamma rays is electromagnetic radiation of high frequency (very short wavelength). Medical diagnostic, Nuklear medicine. SPECT, PET



X-rays can penetrate solid objects, and their most common use is to take images of the inside of objects in diagnostic radiography.

Digital radiography is a form of X-ray imaging, where digital X-ray sensors are used instead of traditional photographic film.

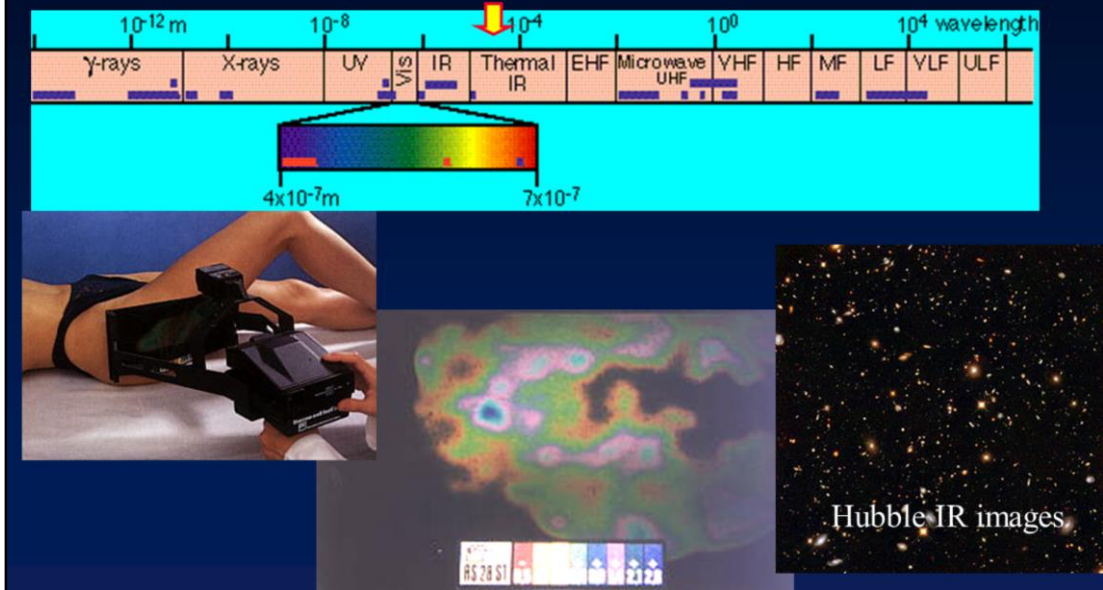
Visible light



The electromagnetic radiation between 380 nanometer and 780 nanometer wavelengths is called light which can be seen for the human eye.

Ophthalmic Photography, Medical photography, Endoscopy, Capsule Endoscope, light microscopy.

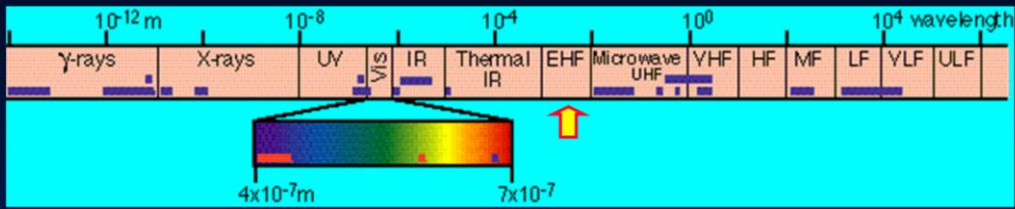
Thermography



This is the "thermal imaging" region, in which sensors can obtain a completely passive picture of the outside world based on thermal emissions only and requiring no external light or thermal source such as the sun, moon or infrared illuminator.

Hubble IR images, remote temperature sensing,

EHF radiowaves



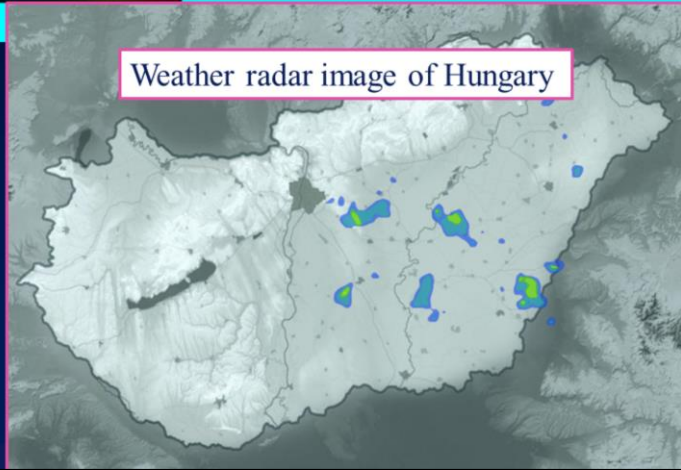
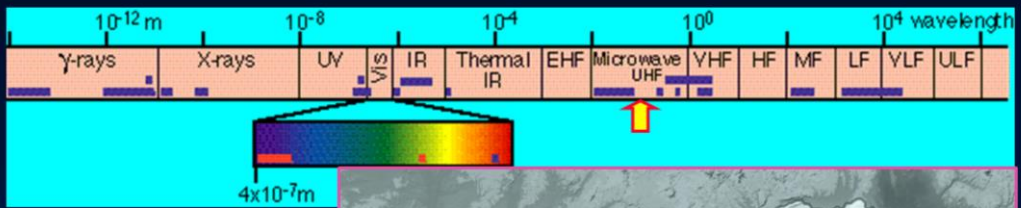
Is it used for imaging?

Extremely high frequency is the highest radio frequency band.

The Super High Frequency (SHF) and Extra High Frequency (EHF) of microwaves come next up the frequency scale.

MRI

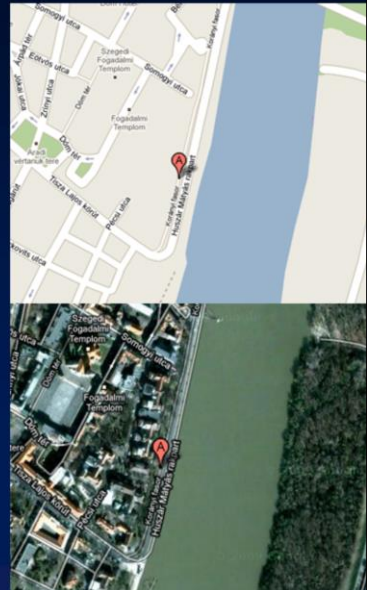
Microwave



Weather radar use microwave radiation

Digital image types

- **Vector images**
mathematical formulas
(circles, rectangles, lines, ...)
are currently treated as separate figures
(maps, drawings, MS Office clipart, ...)
- **Raster or bitmap images**
finite set of digital values (picture
elements or pixels)



Depending on whether or not the image resolution is fixed, it may be of vector or raster type. Without qualifications, the term "digital image" usually refers to raster images also called bitmap images.

Raster images have a finite set of digital values, called picture elements or pixels. The digital image contains a fixed number of rows and columns of pixels. Pixels are the smallest individual element in an image, holding quantized values that represent the brightness of a given color at any specific point.



Vector and raster images

magnification by 6-times



Raster or bitmap image



Vector image

The magnification is the most prominent difference.



More magnification

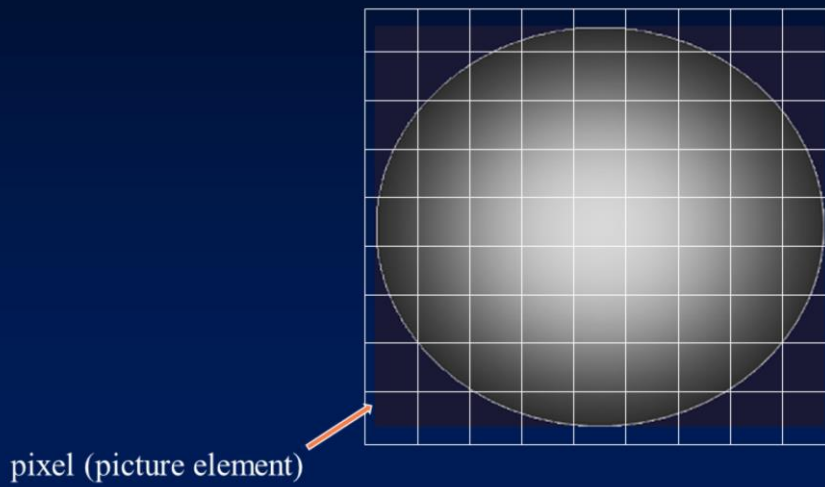


The pixel graphic picture does not disintegrate into dots because the magnification here contains a smoothing, the vector graphic picture can be magnified any times (see Google Map)

Image digitization

Sampling I

Spatial discretization by grids

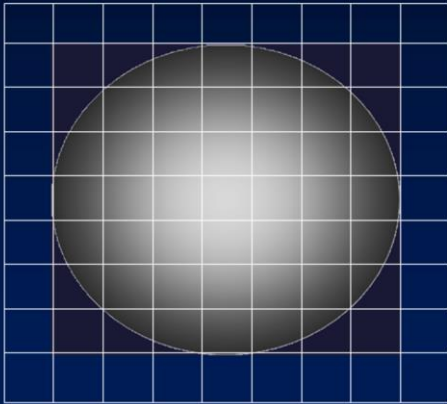


Sampling is a spatial discretization of the image by grids. One element, dot is called pixel (picture element).

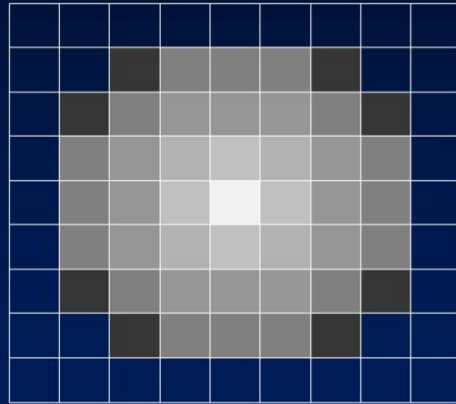
Image digitization

Sampling II

Spatial discretization by grids



Averaging

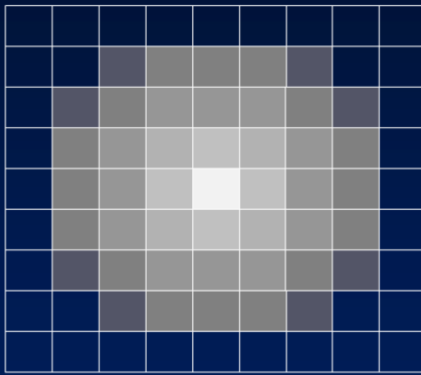


The average of a pixel may yet be considered to have infinite precision at this stage (the value of an analogous sign).

Image digitization

Quantization

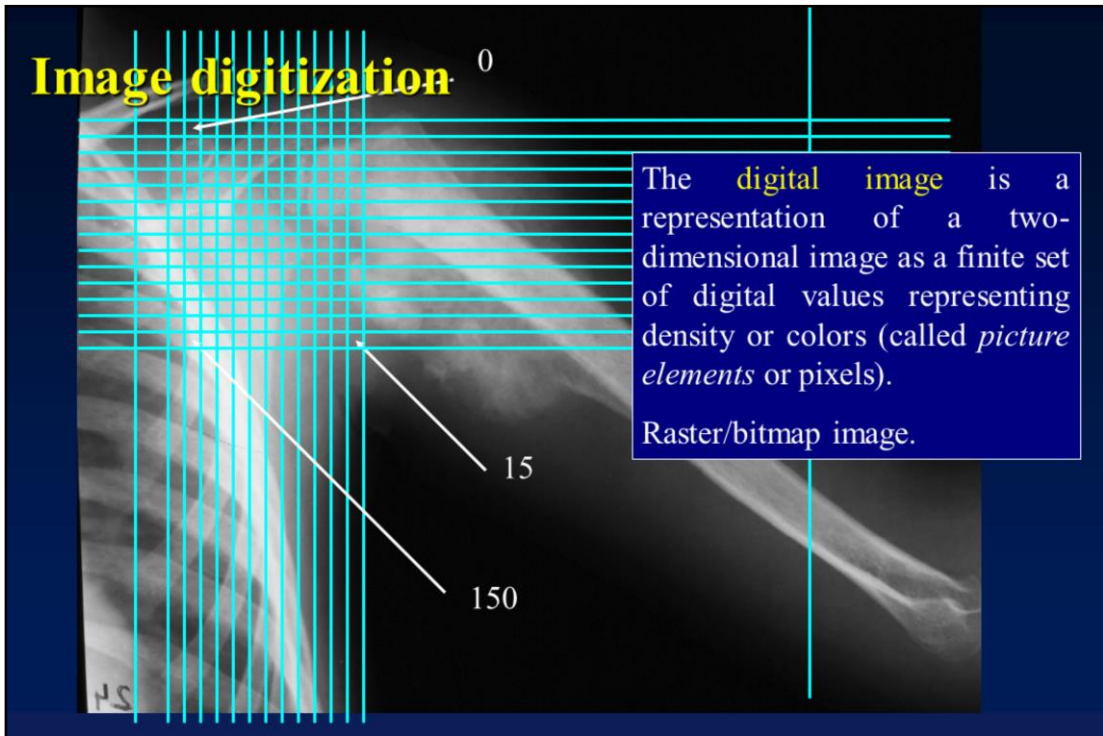
Intensity discretization by quantization



Averages

0	0	0	0	0	0	0	0	0	0
0	0	25	40	40	40	25	0	0	0
0	25	40	64	64	64	40	25	0	0
0	40	64	97	97	97	64	40	0	0
0	40	64	97	150	97	64	40	0	0
0	40	64	97	97	97	64	40	0	0
0	25	40	64	64	64	40	25	0	0
0	0	25	40	40	40	25	0	0	0
0	0	0	0	0	0	0	0	0	0

Quantization: averages are rounded to a fixed set of numbers (such as integers)



A digital image is discretized both in spatial coordinates and brightness.



It can be considered as a matrix whose row, column indices specify a point in the image and the element value identifies gray level value at that point.

These elements are referred to as pixels.

X-ray image and digital value of an apple.

Image digitization

Which year do you think of the first image?



Early digital

1920



Bartlane cable picture transmission system across the Atlantic from > a week to < three

Early 1929



1964

Moon
Ranger 7
minutes before
landing

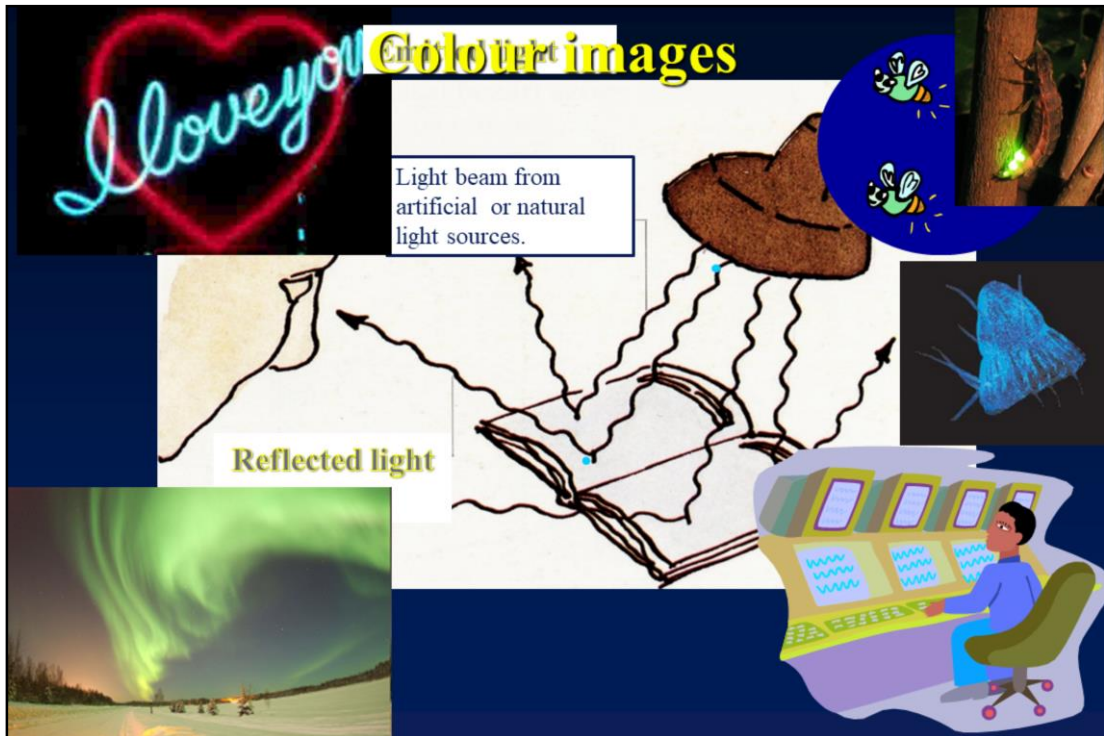
One of the first applications of digital images was digitized newspaper pictures sent by submarine cable between London and New York.

Bartlane cable picture transmission system in the early 1920's reduced the time required to transport a picture across the Atlantic from more than a week to less than three hours. The early Bartlane systems were capable of coding images in five distinct brightness levels.

This was increased to fifteen levels in 1929.

The combined advents of large-scale digital computers and the space program to bring into focus the potentials of digital image concepts. Work on using computer techniques for improving images from a space probe began at the Jet Propulsion Laboratory in 1964, when pictures of the Moon transmitted by Ranger 7 were processed by a computer to correct various types of image distortion inherent in the on-board television camera.

These techniques served as the basis for improved methods used in the enhancement and restoration of images from such familiar programs as the Surveyor missions to the Moon and the Mariner series of flyby missions to Mars.



Before discussing colours let us get clear that there are two ways to see objects:

The object either reflects or emits light .

Neon light, bioluminescence, displays, aurora borealis (the northern lights) or aurora australis (the southern lights),

Colour images, colour systems

Additive colour system **RGB**
Colours are summed

Primary colours:
Red
Green
Blue

Secondary colours:
Cyan
Magenta
Yellow

R+B LIGHT = MAGENTA
G+R LIGHT = YELLOW
G+B LIGHT = CYAN

The additive colour is the mixing of various wavelength lights. The three primary colours: red, green, blue (RGB).

The white colour can be achieved with the mixing of the three primary colours of identical intensity (the most complex light).

Additive (RGB)

A Grand Tetons

R+G+B



<http://chemistry.beloit.edu/Stars/pages/colormix.html>

With the mixing of the bundles of the single colour components with different intensity can be reached the various colours.

The white colour can be achieved with the mixing of the three primary colours of identical intensity (the most complex light).

Colour image of Grand Tetons = R+G+B components

Colour images

height = 480

Color pixel

80 111 20

(0,255,0) represents green.

Which colour is represented by (255,255,255)?

pixel (picture element)

16 bit High Color

24 bit = 3x8 bit True Color

32 bit = 3x8 bit + 8 bit alpha channel

red green blue α

The computerised depiction of a color pixel. A pixel is divided into 3 bytes. The RGB components can be found in every byte. In the case of colored pictures the following color depths are typical:

8 bit, 256 colors

16 bit, more than 65.000 colors - **high color**

24 bit, more than 16 million colors - **true color**

RGB

800000	8E0000	FF0000	FFB6C1	DC143C
maroon	darkred	red	lightpink	crimson
DE7093	FF69B4	FF1493	C71585	800080
palevioletred	hotpink	deeppink	mediumvioletred	purple
8B008B	DA70D6	D8BFD8	DDA0DD	EE82EE
darkmagenta	orchid	thistle	plum	violet
FF00FF	FF00FF	BA55D3	9400D3	9932CC
fuchsia	magenta	mediumorchid	darkviolet	darkorchid
8A2BE2	4B0082	9370DB	6A5ACD	7B68EE
blueviolet	indigo	mediumpurple	slateblue	mediumslateblue
00008B	0000CD	0000FF	000080	191970
darkblue	mediumblue	blue	navy	midnightblue
483D8B	4169E1	6495ED	B0C4DE	F0F8FF
darkslateblue	royalblue	cornflowerblue	lightsteelblue	aliceblue
F8F8FF	E6E6FA	1E90FF	4682B4	00BFFF
ghostwhite	lavender	dodgerblue	steelblue	deepskyblue
708090	778899	87CEFA	87CEEB	ADD8E6
slategray	lightslategray	lightskyblue	skyblue	lightblue
008080	008B8B	00CED1	00FFFF	48D1CC
teal	darkcyan	darkturquoise	aqua, cyan	mediumturquoise
5F9EA0	AFEEEE	E0FFFF	F0FFFF	20B2AA
cadetblue	paleturquoise	lightcyan	azure	lightseagreen
40E0D0	B0E0E6	2F4F4F	7FFFD4	00FA9A
turquoise	powderblue	darkslategray	aquamarine	mediumspringgreen
66CDAA	00FF7F	3CB371	2E8B57	32CD32
mediumaquamarine	springgreen	mediumseagreen	seagreen	limegreen
006400	008000	00FF00	228B22	8FBC8F
darkgreen	green	lime	forestgreen	darkseagreen
90EE90	98FB98	F5FFFA	F0FFF0	7FFF00
lightgreen	palegreen	mintcream	honeydew	chartreuse
7CFC00	6B8E23	556B2F	9ACD32	ADFF2F
lawngreen	olivedrab	darkolivegreen	yellowgreen	greenyellow

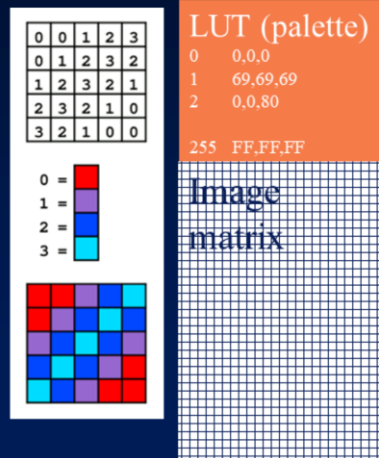
binary	Hexadec.	Decimal
0000	0	0
0001	1	1
1010	A	10
1111	F	15

F5F5DC	FAF0E6	FAFAD2	808000	FFFF00
beige	linen	lightgoldenrodyellow	olive	yellow
FFFFE0	FFFFF0	BDB76B	F0E68C	EEE8AA
lightyellow	ivory	darkkhaki	khaki	palegoldenrod
F5DEB3	FFD700	FFFACD	FFEDF5	B8860B
wheat	gold	lemonchiffon	papayawhip	darkgoldenrod
DAA520	FAEBD7	FFF8DC	FDF5E6	FFE4B5
goldenrod	antiquewhite	cornsilk	oldlace	moccasin
FFDEAD	FFA500	FFE4C4	D2B48C	FF8C00
navajowhite	orange	bisque	tan	darkorange
DEB887	8B4513	F4A460	FFB6CD	FFF0F5
burlywood	saddlebrown	sandybrown	blanchebonnet	lavenderblush
FFDAB9	FFFAF0	FFF0F0	CD853F	FFDAB9
peachpuff	floralwhite	snow	peru	peachpuff
D2691E	A0522D	FFA07A	FF7F50	E9967A
chocolate	sienna	lightsalmon	coral	darksalmon
FFE4E1	FF4500	FA8072	FF6347	BC8F8F
mistyrose	orangered	salmon	tomato	rosybrown
FFC0CB	CD5C5C	F08080	A52A2A	B22222
pink	indianred	lightcoral	brown	firebrick
000000	696969	808080	A9A9A9	C0C0C0
black	dimgray	gray	darkgray	silver
D3D3D3	DCDCDC	F5F5F5	FFFFFF	
lightgray	gainsboro	whitesmoke	white	

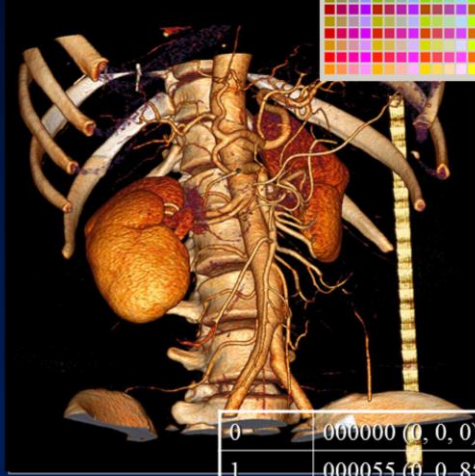
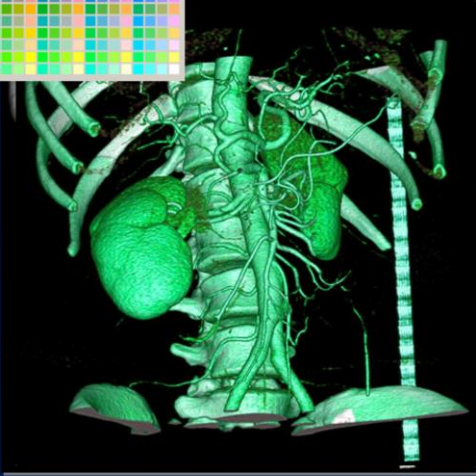
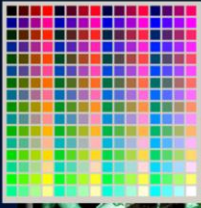
RGB colours. 8 bits 2 hexadecimal numbers.

Indexed colour

A 2-bit indexed colour image.
The colour of each pixel is represented by a number; each number (the index) corresponds to a colour in the colour table (the palette).



Look Up Table (LUT)



0	000000 (0, 0, 0)
1	000055 (0, 0, 85)
255	FFFFFF (255, 255, 255)

Colour images

Subtractive colour system CMY
Colours are subtracted
(from white)

red apple
(the apple does not radiate red light, it swallows every color from the white except red)

Which colours does the red apple absorb?

The subtractive colour system has the feature, that from the white light (implying all color shades) some are reflected, others are swallowed, subtracted.

The colour of the object is the mix of reflected colour.

The primary colours of this system are: **Cyan, Magenta, Yellow.**

In case of typographical applications dark colours stirring from the three primary colours is expensive and not clear, therefore black is used as a fourth colour.

The apple does not have a colour, does not radiate red light, it swallows everything from the white colour except red.

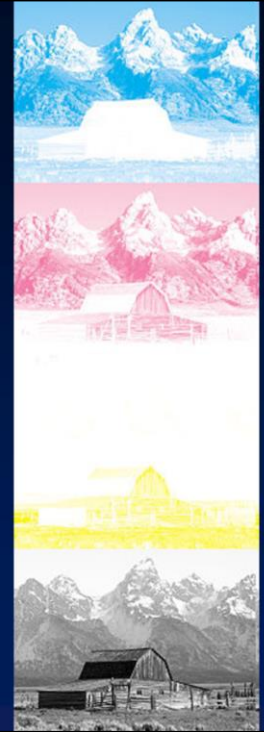
Colour image of Grand Tetons



cián, magenta and yellow ink



+ black ink (to spare colour inks)



In the case of typographical applications dark colours stirring from the three primary colours is expensive and not clear, therefore black is used as a fourth colour.

Propertis of digital images

- Spatial resolution
- Pixel resolution



Spatial resolution

Image resolution describes the detail an image holds. The term applies to digital images, film images, and other types of images. Higher resolution means more image detail.

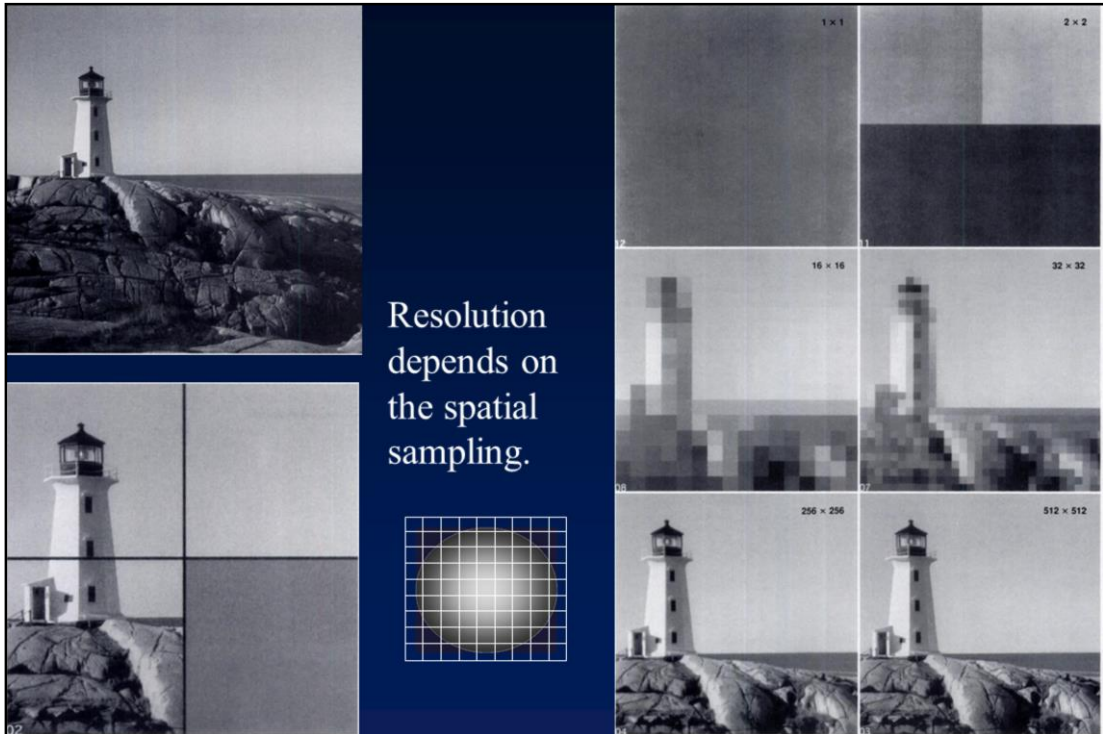
Units:

- pixels per length unit or pixels per area unit
 - dots per inch (dpi: printer)
 - line pairs per millimeter (lp/mm: X-ray film, photo)
- number of pixel: 5 Megapixel, 2500x2000, 512x512
Monitor: SVGA (800×600), XGA (1024×768), UXGA (1600×1200).

Spatial resolution describes **the ability of any image-forming device** such as an optical or radio telescope, a microscope, a camera, or an eye, **to distinguish small details of an object.**

Image resolution describes the detail an image holds. The term applies to digital images, film images, and other types of images. Higher resolution means more image detail.

But when the pixel counts are referred to as resolution, the convention is to describe the pixel resolution with the set of two positive integer numbers, where the first number is the number of pixel columns (width) and the second is the number of pixel rows (height), for example as 640 by 480. Another popular convention is to cite resolution as the total number of pixels in the image, typically given as number of megapixels, which can be calculated by multiplying pixel columns by pixel rows and dividing by one million. Other conventions include describing pixels per length unit or pixels per area unit, such as pixels per inch or per square inch.



Resolution depends on the spatial sampling (spatial discretization).

The digitization process begins by dividing the image into a number of regions called pixels (here, four), which are each filled with a single density. The lower right pixel is uniformly filled with the average density of the corresponding region of the original image.

Spatial image resolution

40x40

1 pixel = 2x2 mm

80x80

1 pixel = 1x1 mm

800x800

1 pixel = 0,1x0,1 mm



Image property: resolution

Scanned chest.

Eddig!!!!!!!!!!!!!!!!!!!!!!

Colour depth or bit depth of digital (bitmapped) images

Colour depth or bit depth is the number of bits used to represent the colour of a single pixel in a bitmapped image = **Pixel resolution**

1 bit (2 colours)



4 bits (16 colours)



8 bits (256 colours)

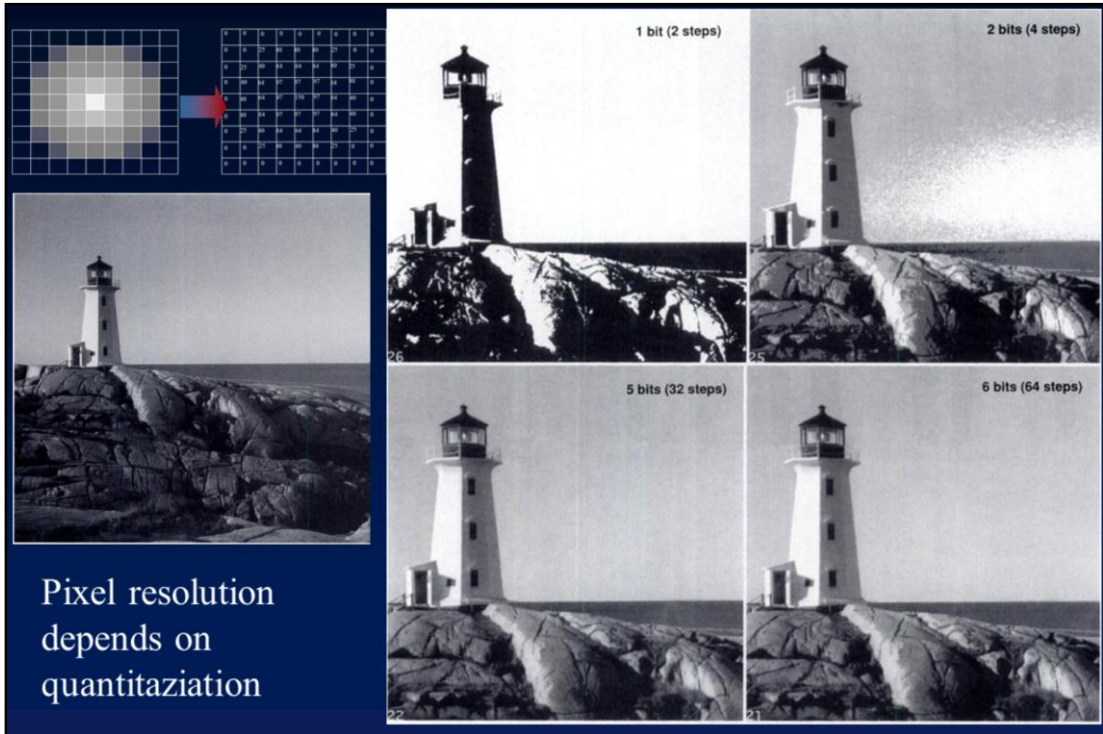


Colour depth or bit depth is the number of bits used to represent the color of a single pixel in a bitmapped image

- 1 bit = 1+1 color (eg. Black and white).
- 8 bit (1 byte) = 256 color- or shadow density.
- 3 x 8 bit (3 byte) = 3 color x 256 density= 16 million color. + 8 bit – alfa channel = 256 opacity.
- 3 x 12 bit = 3 x 4096

Pixel resolution determines how finely a system can represent or distinguish differences of intensity, and is usually expressed as a number of levels or a number of bits, for example 8 bits or 256 levels that is typical of computer image files. The higher the radiometric resolution, the better subtle differences of intensity or reflectivity can be represented, at least in theory. In practice, the effective radiometric resolution is typically limited by the noise level, rather than by the number of bits of representation.

In computer graphics, color depth or bit depth is the number of bits used to represent the color of a single pixel in a bitmapped image or video frame buffer. This concept is also known as bits per pixel (bpp), particularly when specified along with the number of bits used. Higher color depth gives a broader range of distinct colors.



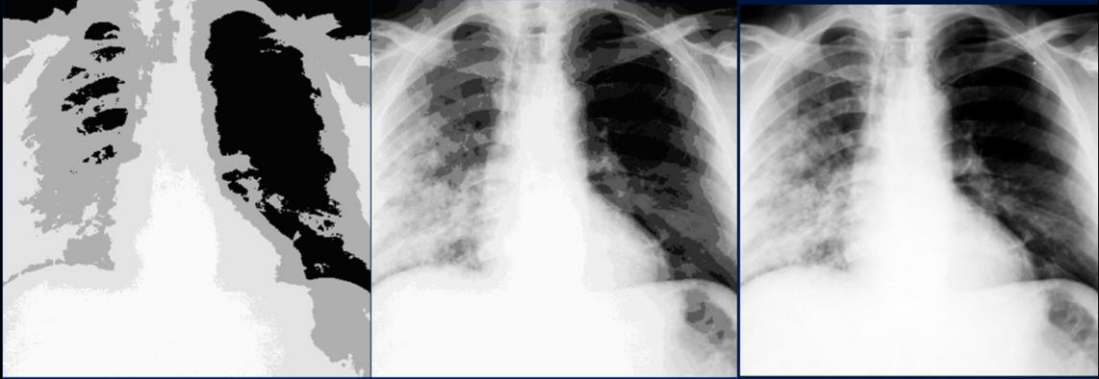
Images demonstrate the effect of bit depth on image quality. Use of too few steps causes the 'clouds' seen in the 2-bit images. These are artifactual contours produced by insufficient bit depth.

Colour depth or bit depth

2 bit (4 colours)

4 bits (16 colours)

8 bits (256 colours)



2 bits, 4 bits, 8 bits

Related questions

- Information (definition, theory, bit)
- Image, digital image, pixel
- Digital image types
- Digitization, sampling, quantization
- Electromagnetic rays in imaging
- Colours, colour systems: RGB
- Properties of digital image (resolution, colour images, colour palette, high colour, true colour)