Mobile Programming and Multimedia

Images

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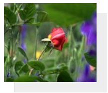
Images: fundamentals

An image is an area with a defined colors distribution

A digital image is a bidimensional matrix, and each point has a chromatic information

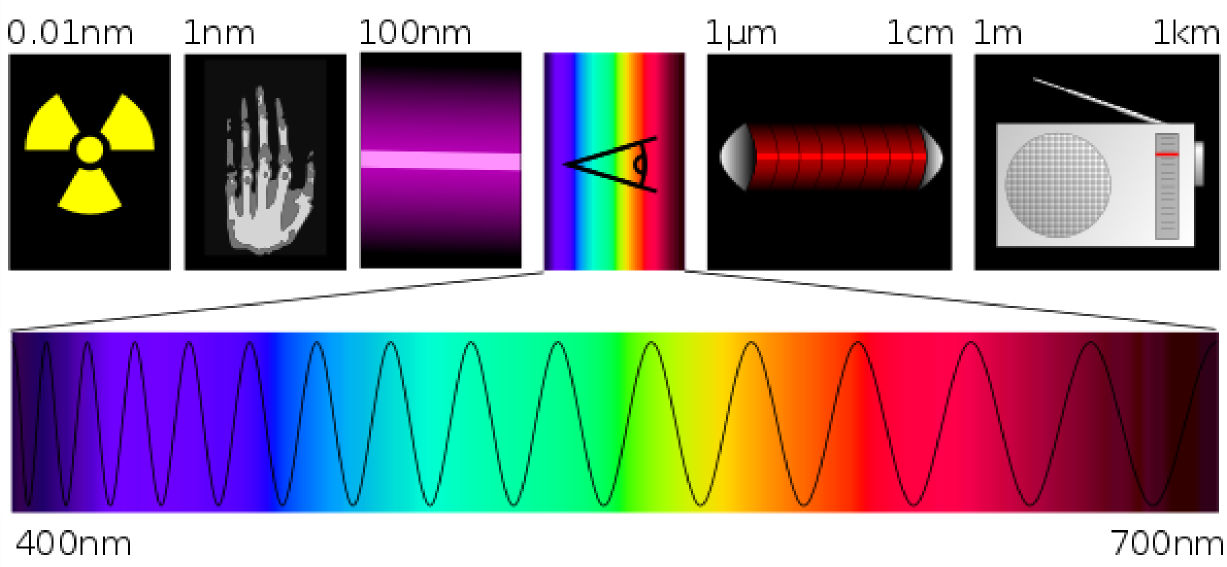
The digitalization of an image is a two-step process:

- *Spatial sampling*
- *Chromatic quantization*



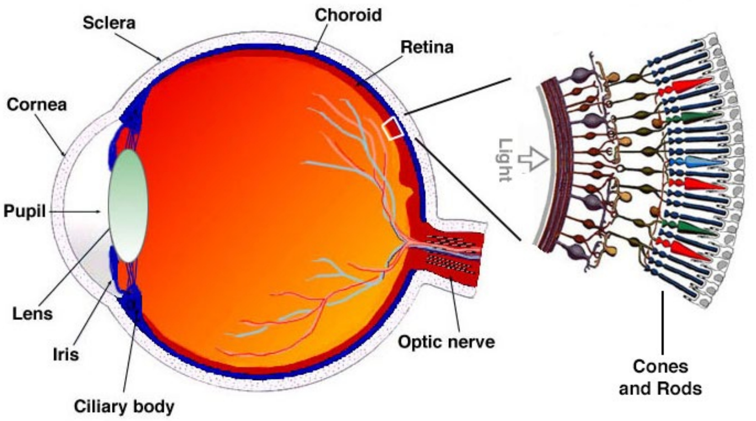
Human eye sensibility - 1

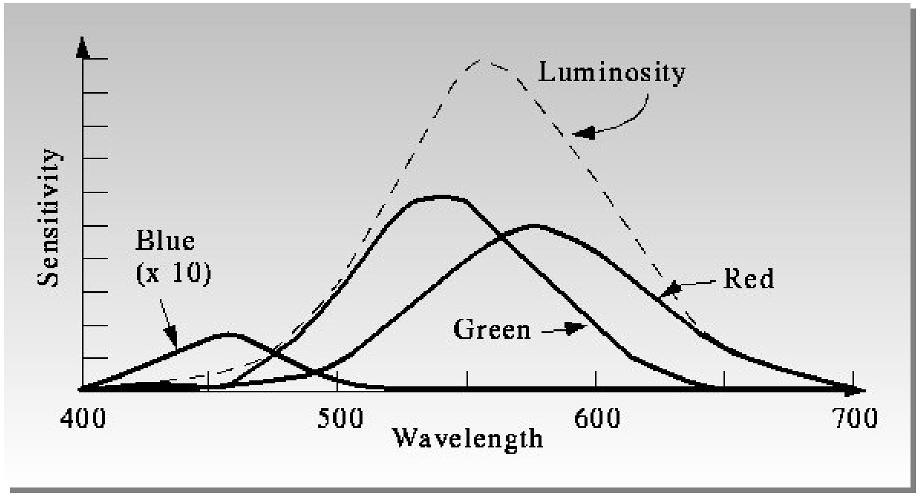
The visible spectrum is the portion of the electromagnetic spectrum visible to the human eye. Wavelength is between 380 to about 750 nanometers



Human eye sensibility - 2

The retina of the human eye has rods and cones



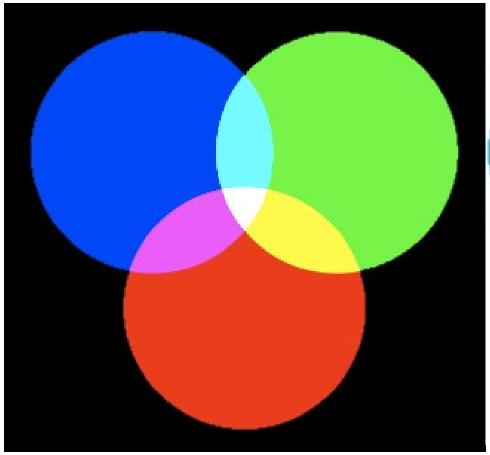


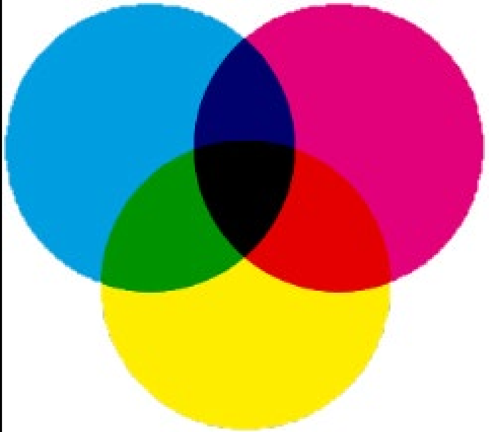
- Rodes are responsible for night vision
- Cones are of three types, responding respectively to red, blue and green colors

Color representation (1)

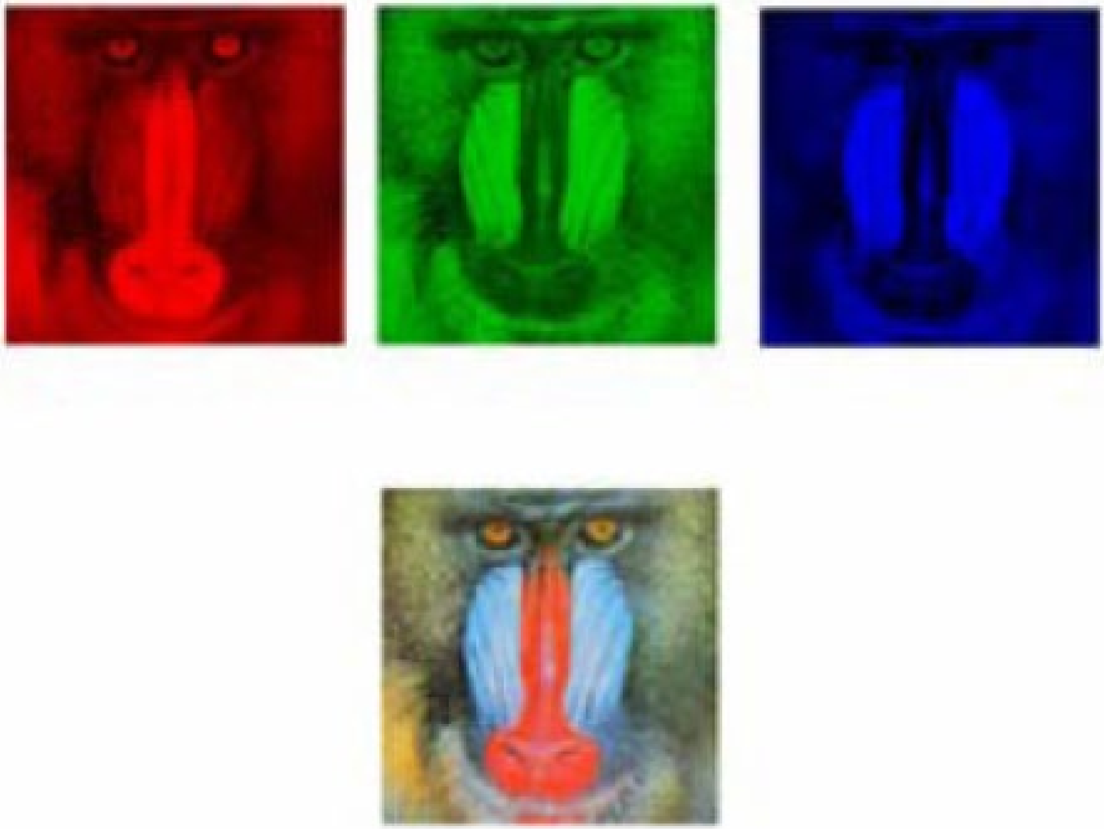
There are two different models to represent colors, as a combination of primary colors:

- Additive color: **RGB**
  - Monitor, transmitted light
- Subtractive: **CYMK**
  - Printers and other devices for printing

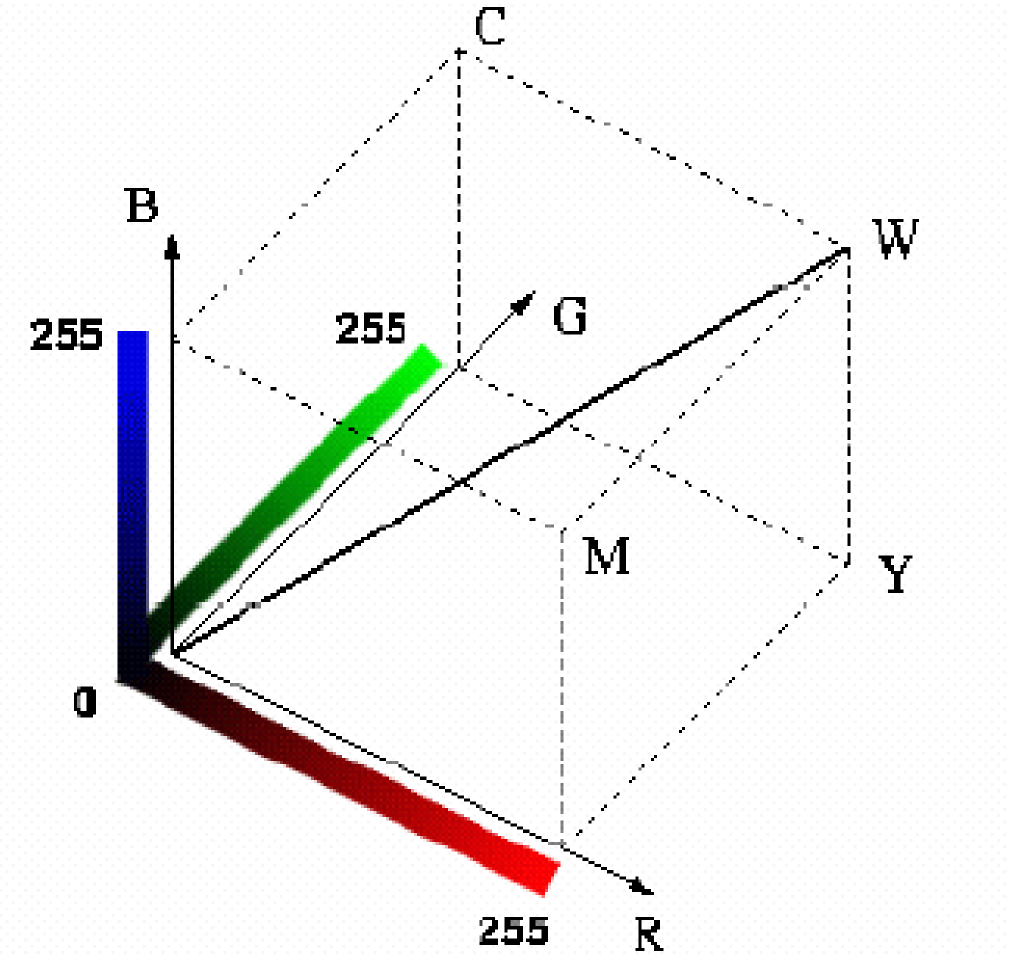




RGB Example



RGB and CMYK



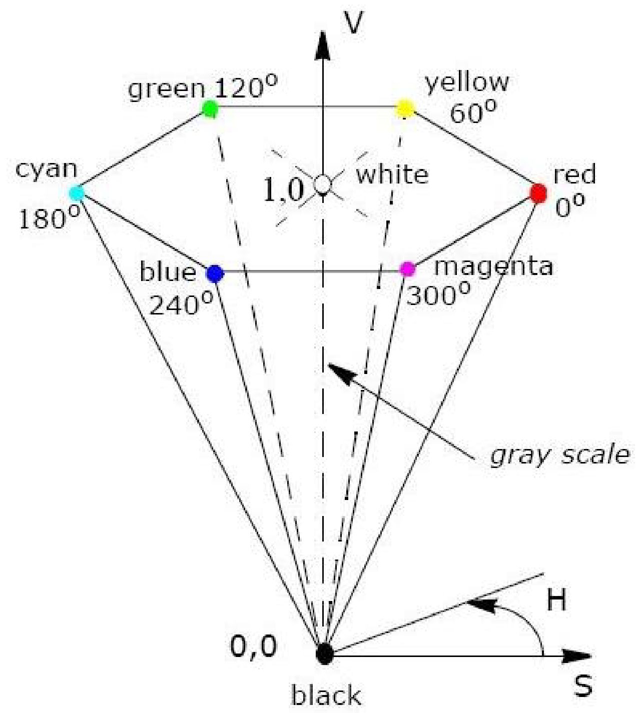
R = red
G = green
B = blue

C = Cyan
M = magenta
Y = yellow
K = black

Color representation (2)

Through a color space based on psychophysical characteristics

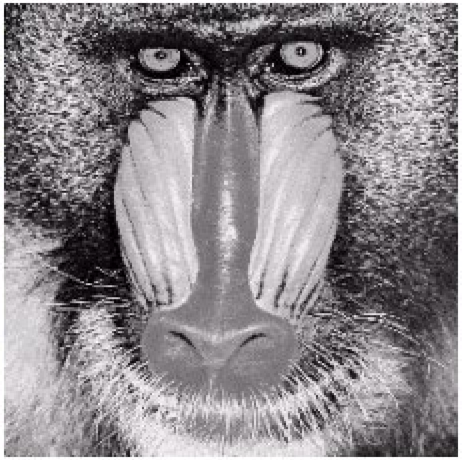
- **HSV**: hue, saturation e intensity (value) (same as luminosity)
- **YUV**, **YIQ**, **YCbCr**, separate information about luminosity (luminance) from color information (chrominance)
  - TV – PAL, NTSC, digital TV



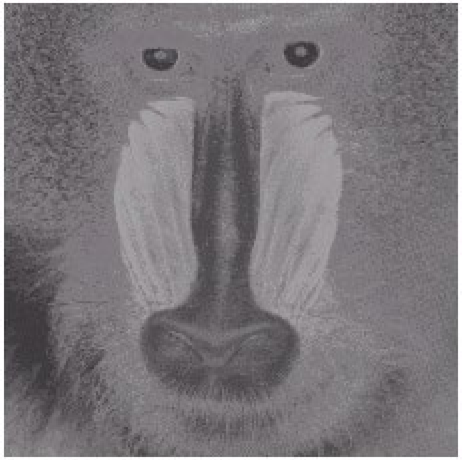
Channels breakdown

YUV example

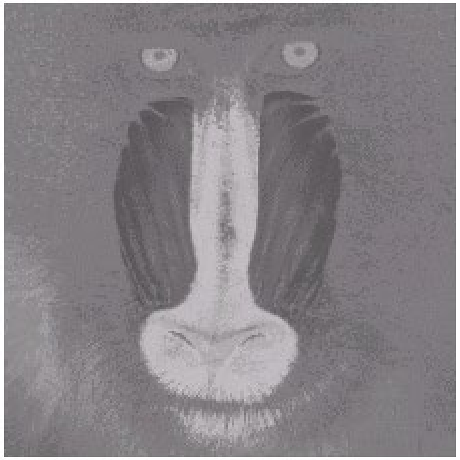
Original



Y component



U component

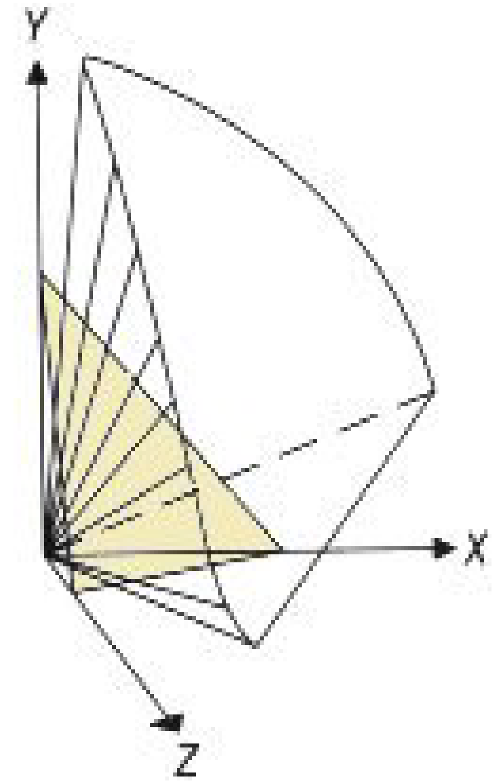


V component

CIE model - 1

Color spaces considered until now are strictly related to the devices used for visualization

CIE XYZ: in *tristimulus* representation system, values depend on spectrum properties of the cones. This model represents the whole human color vision.



With symbols:

$x = X/(X+Y+Z);$

$y = Y/(X+Y+Z);$

$z = Z/(X+Y+Z);$ so

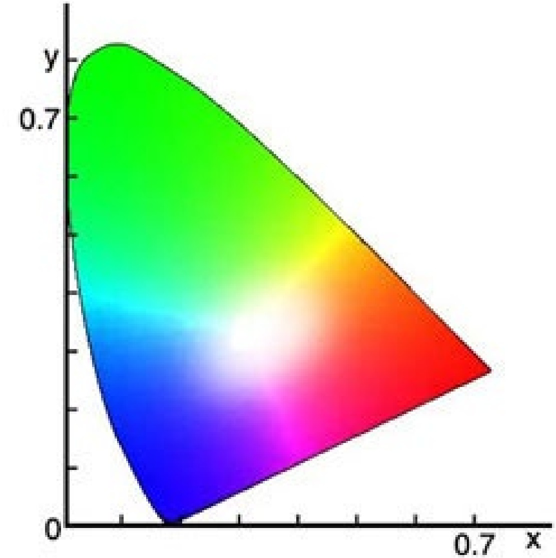
$x + y + z = 1$

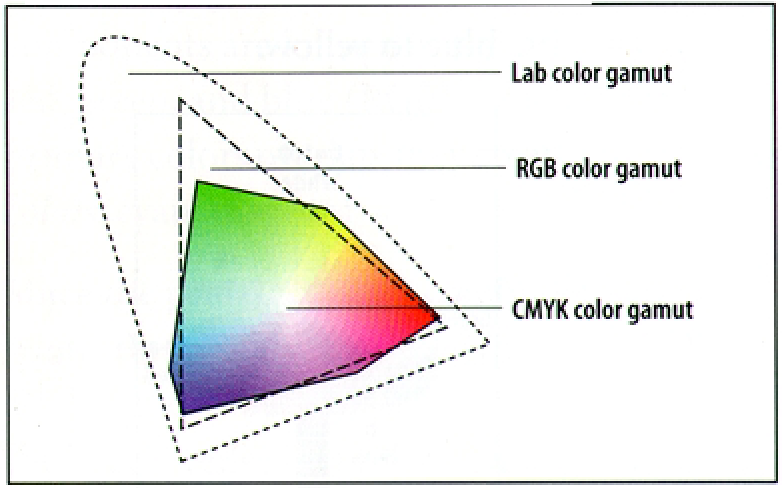
CIE model - 2

The horseshoe curve represents pure colors.

The line of purples connects the extreme points of the shapes and represents colors with does not correspond to a wavelength.

At the center of the diagram, there are some reference colors (Illuminating, E, A, B, C, D)





Images: properties

Color depth

- Monochromatic images and grayscale images (1 bit, 8 bit)
- Indexed colors: usually 8 bit/256 colors chosen between ??? (palette or CLUT, *Color Look-Up Table*)
- True colors: 24 bit/16.7M colors, 48 bit (High Definition), 24 + 8 bit (*alpha channel*)

Resolution

- Limited to the more common sizes of the screens for Web applications
- Images can be encoded with multiple resolutions
- Miniature for fast preview

BitMap - BMP

MS Windows native format for images

It can represent images

- With a palette (*colormap*) at 1, 4 or 8 bits per pixel
- With natural colors using 24 bit per pixel

- Not compressed
- Compressed using RLE algorithm

Particularly suited for artificial images or images with several sequences of equal pixels

Not suitable for photographic images

Palette

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It is possible to use a standard palette with a subset of possible colors, dividing the RGB cube by a standard number for each channel

With 256 colors, with 6 steps we get 216 equally spaced colors. Other colors are freely chosen.

Optimized Palette: built from the histogram, it best represents colors of the picture.

Palette comparison

Immagine originale a 24 bit

Immagine a 8 bit con palette standard

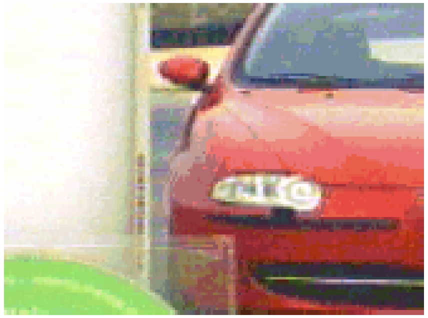
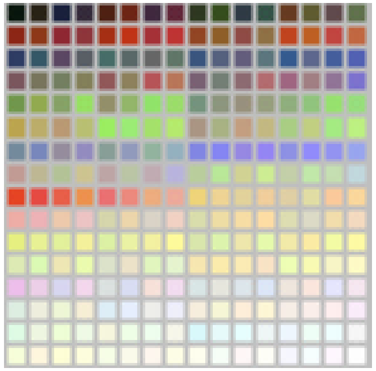


Immagine a 8 bit con palette ottimizzata



Images: storage space

Memory occupation depends on color depth and image size

- Grayscale 160 x 120 = 18.75 Kbyte
- 256 indexed colors 640 x 480 = 300 Kbyte
- *true color* 1024 x 768 = 2.25 Mbyte
  (images not compressed)

Compression strongly reduces size

- 1024 x 768 JPEG ≅ 300 Kbyte

Images: transfer time

Transfer time for not compressed images is usually not acceptable even with fast network connections

- 2,25 Mbyte with ADSL 640 Kbit $\cong$ 29 sec.

Compressed JPEG image requires less time

- 300 Kbyte with ADSL 640Kbit $\cong$ 4 sec.
- Decompression time is irrelevant with the actual workstation

Intervals of time needed are even shorter if the image is only visualized on the screen

- Quality requirements are usually lower than print requirements

Image formats

Independent from the platform and producer

Usually do not require a license (except GIF in the past)

- **GIF**: 8 bits, animation, transparency
- **JPEG**: *true color*, quality, lossy compression
- **PNG**: lossless compression, *alpha channel*, extensibility

GIF, Graphics Interchange Format

The first standard for image transmission over networks

Developed by Unisys and Compuserve

256 indexed colors

Compression algorithm: LZW (patent Unisys, expired in 2004)

Other properties: interlacing, transparency, animations

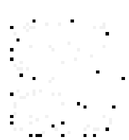
GIF: why & when

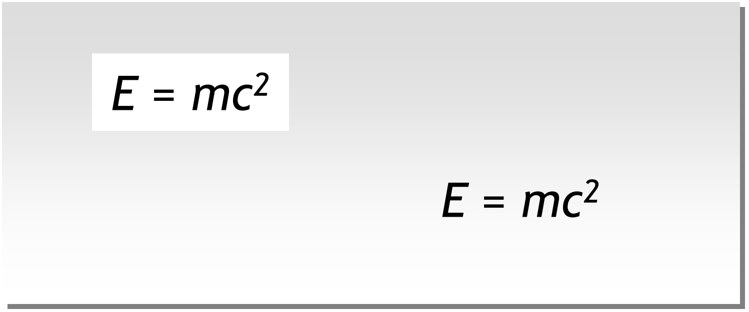
Simple images with few different colors (artificial images)

Lossless compression, fast decoding

Animated images are usually engaging and make messages more visible (advertisement)

Transparency allows better integration with the background (ex. formulas)





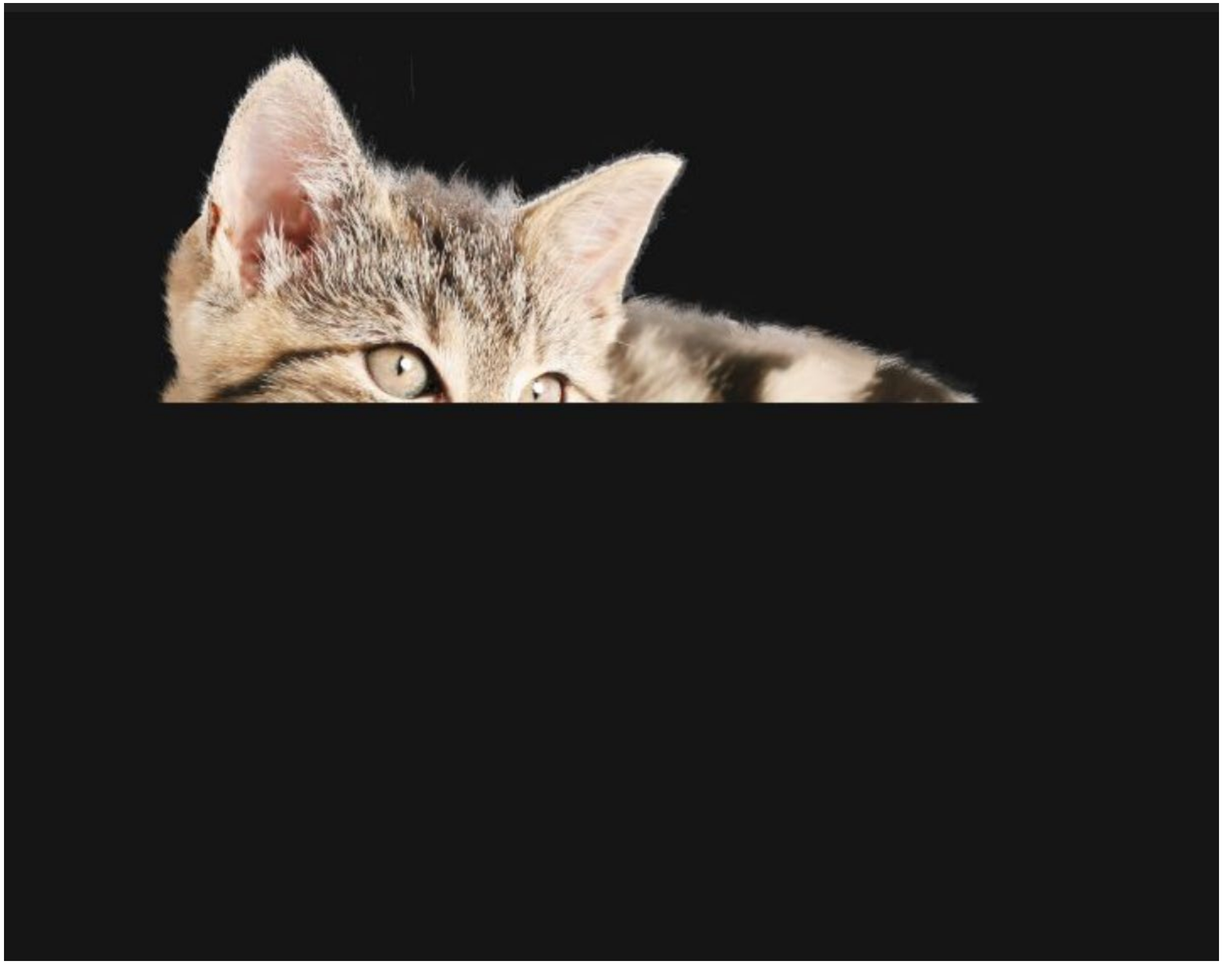
PNG, Portable Network Graphics

- It is an extensible format, with lossless compression, portable, for colorful images
- No patents and licenses (to substitute GIF)
- Color depth is variable from 1 to 16 bit
- Supports indexed colors, grayscale images, and *true color images*
- Transparency effects using an optional *alpha channel*
- Implements an efficient interlacing method for images transmitted through the network
- W3C recommendation

1	6	4	6	2	6	4	6
7	7	7	7	7	7	7	7
5	6	5	6	5	6	5	6
7	7	7	7	7	7	7	7
3	6	4	6	3	6	4	6
7	7	7	7	7	7	7	7
5	6	5	6	5	6	5	6
7	7	7	7	7	7	7	7

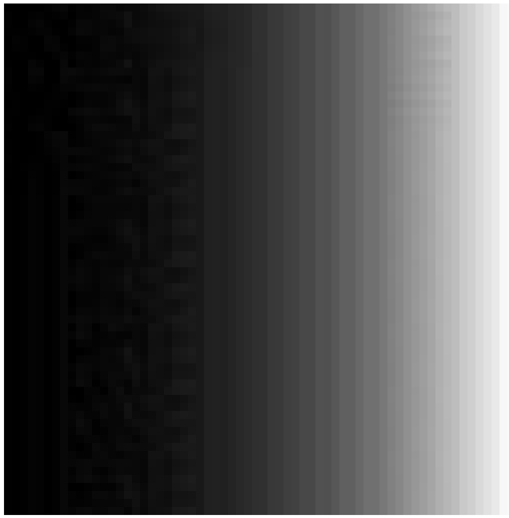
Interlacing - original

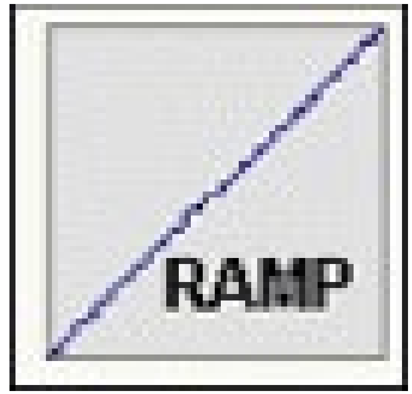
Half data – without interlacing



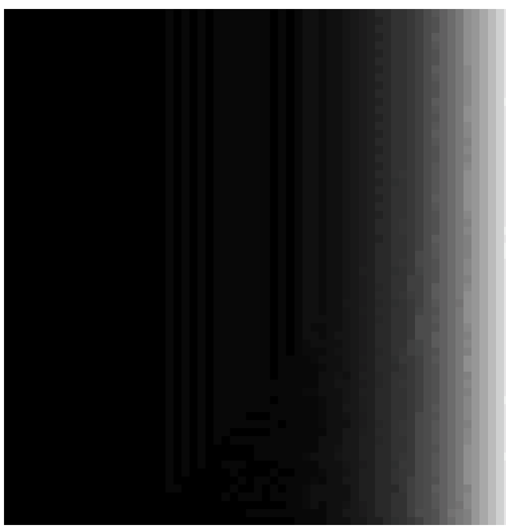
With interlacing

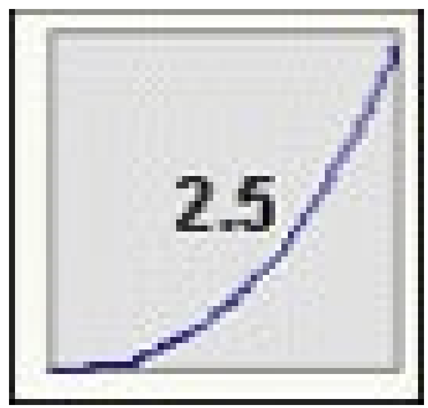
Gamma correction - 1





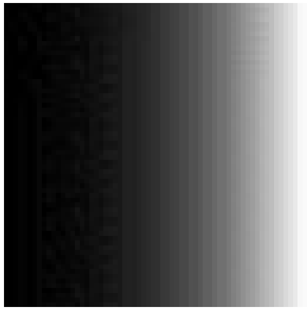
Input

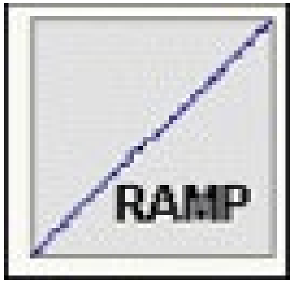




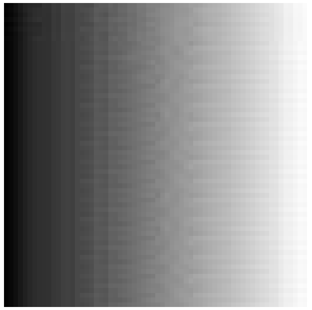
Output (typical monitor)

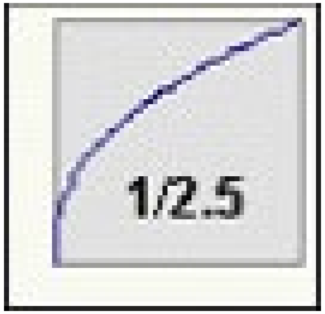
Gamma correction - 2



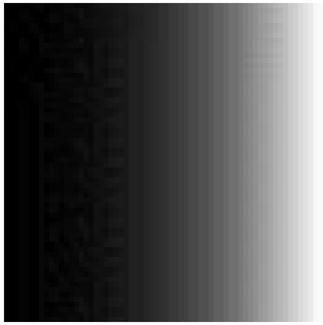


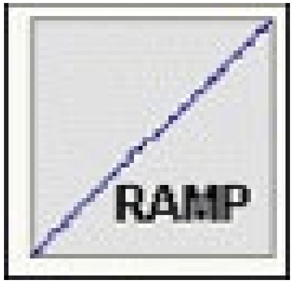
Input





Gamma Correction





Output (typical monitor)

Example

PNG: why & when

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It has the same uses as the GIF format without requiring a license

Equal or better quality than the JPEG format, but with a lower compression

Allows a higher control of the different effects of the image through the ***alpha channel***

It is extensible to insert additional information or proprietary information in a standard way

Promoted by W3C

JPEG, Joint Photographic Experts Group

It is the standard for photographic images compression (1992)

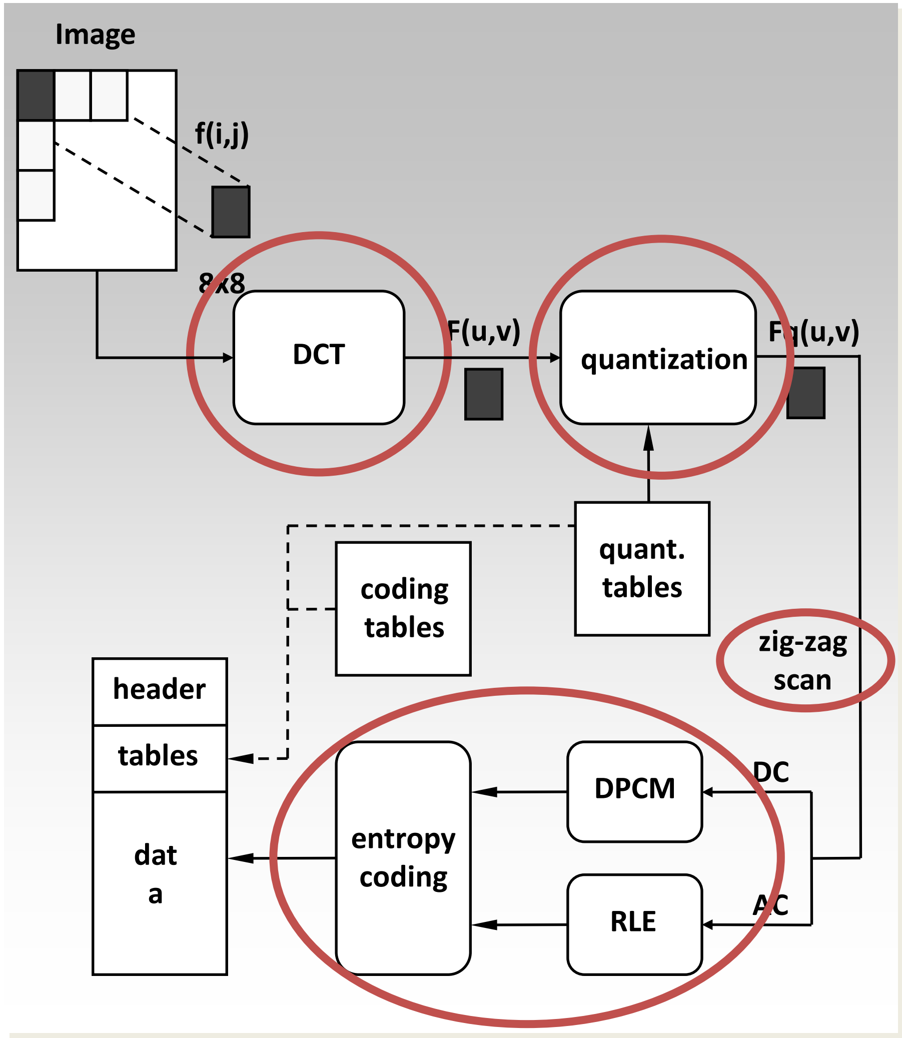
Overcomes the limitation of the entropic compression, using the redundancy of visual perception

- Smallest details of an image can be suppressed without losing useful information

JPEG: Compression algorithm

Encoding in 6 phases:

1. Image preparation
2. For each 8x8 block, a DCT (Discrete Cosine Transform) is applied, generating an 8x8 matrix where the element (0,0) is the dominant color, while the other values rapidly tend to 0
3. quantization: each coefficient is divided by a weight defined in a quantization table
4. The value (0,0) is substituted with the difference with the same value of the adjacent matrix. The purpose is to obtain low values
5. Matrix Linearization: the obtained matrix is covered diagonally, and not by columns or rows, to get adjacent values equal to zeros
6. Compression: RLE and Huffman encoding to the resulting list of values



JPEG: color representation

Human being perception is more precise for luminosity than for colors

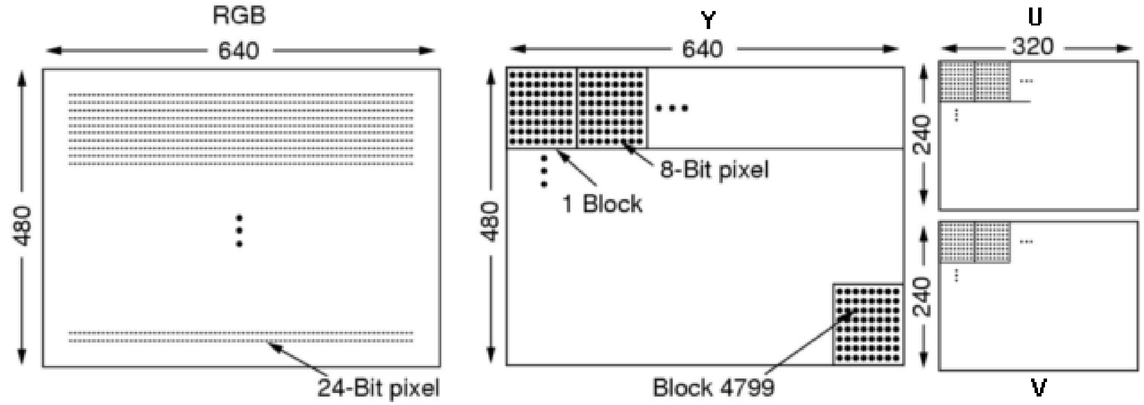
- The representation of luminance information must be more accurate than the chrominance information
- Different resolutions for the two components

Color coding YUV

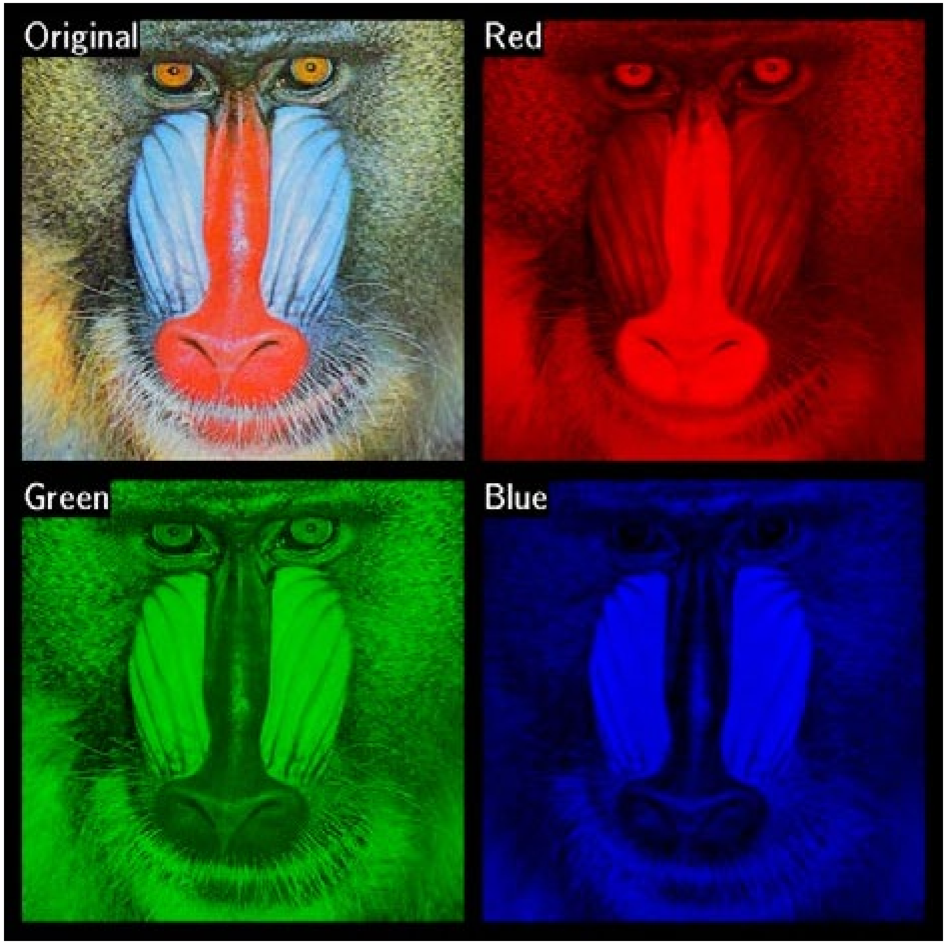
- Y (luminance) is a combination of the RGB components
- U e V (chrominance) are encoded as differences to the reference colors:

$$U = B - Y,\ V = R - Y$$

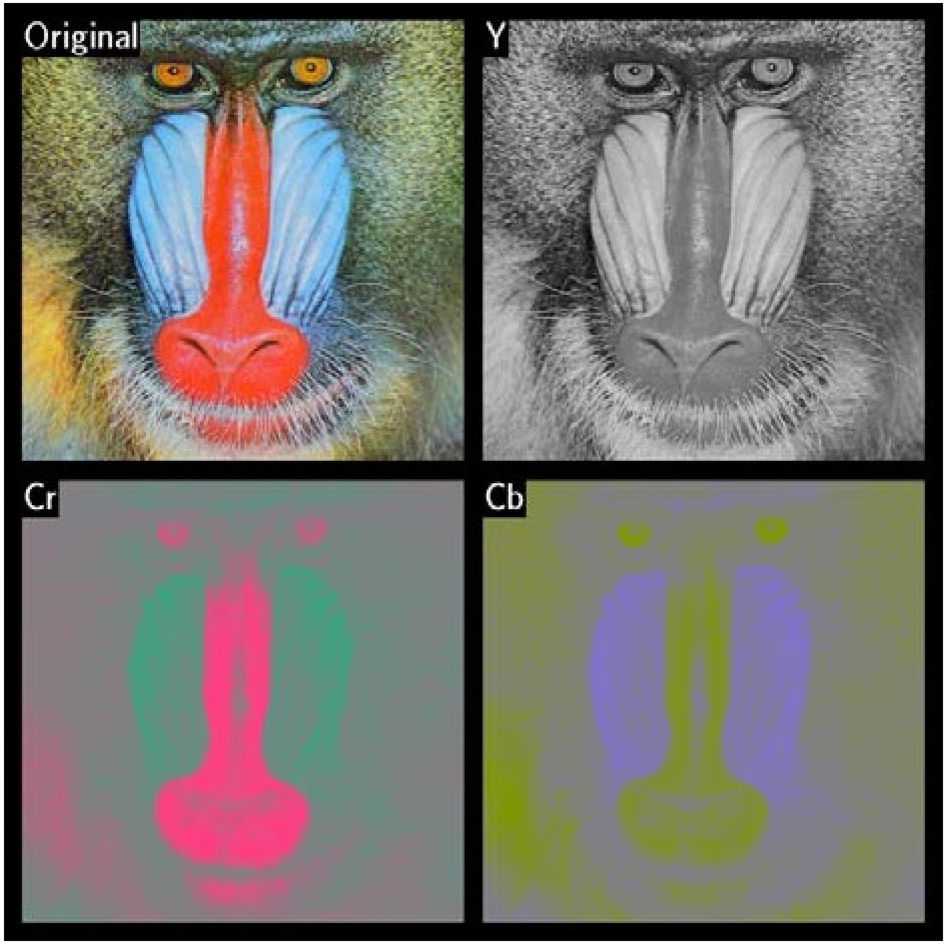
- U and V are undersampled



Color Space Transformation: RGB



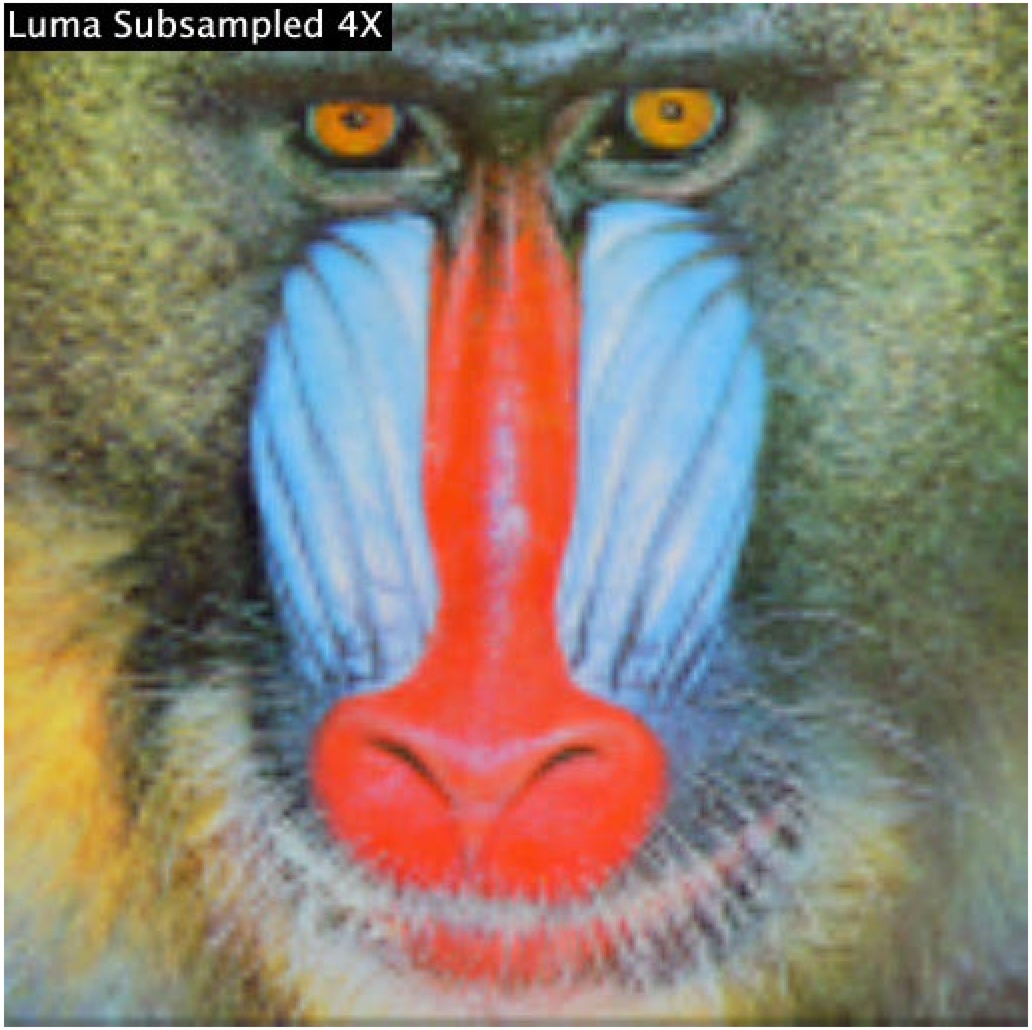
Color Space Transformation : YCbCr



Undersampling: original

Undersampling: luminance 2x

Undersampling: Luminance 4x



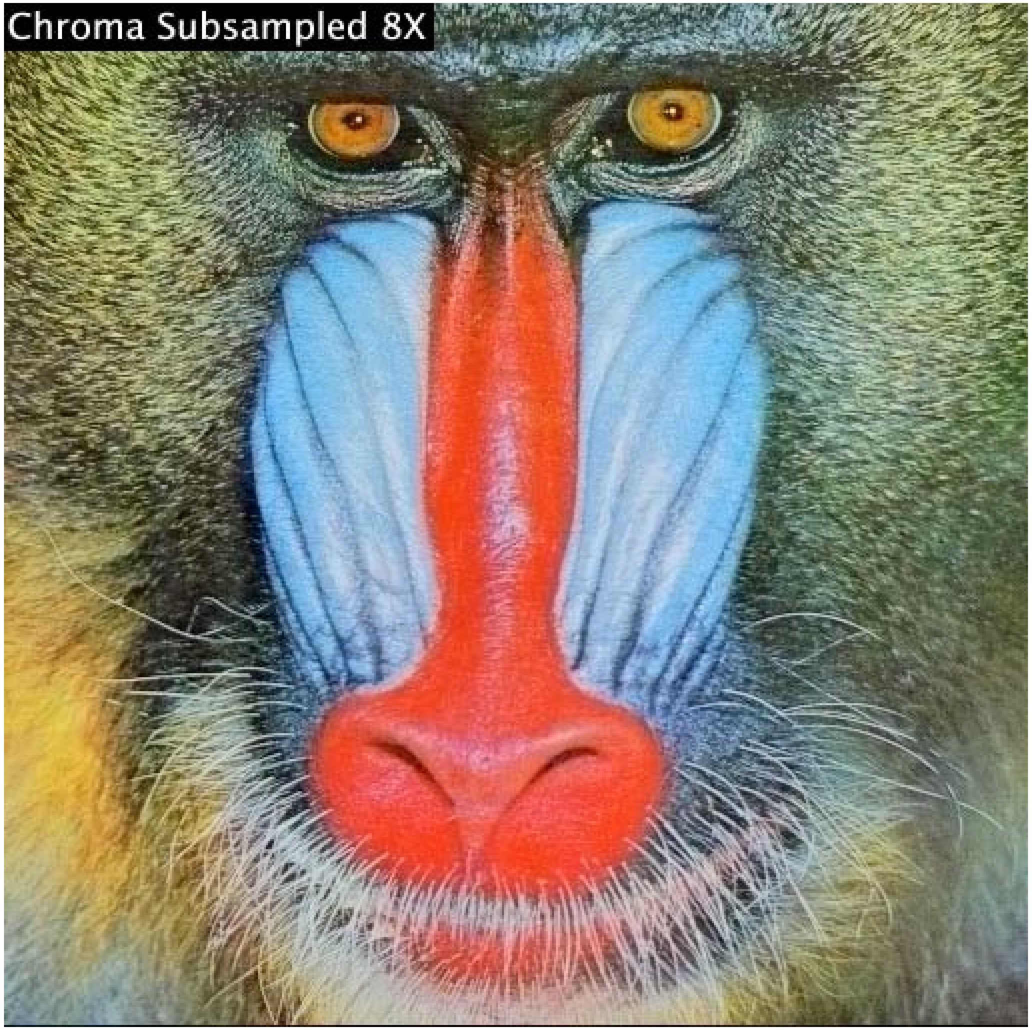
Undersampling: luminance 8x

Undersampling: original

Undersampling: chrominance 2x

Undersampling: chrominance 4x

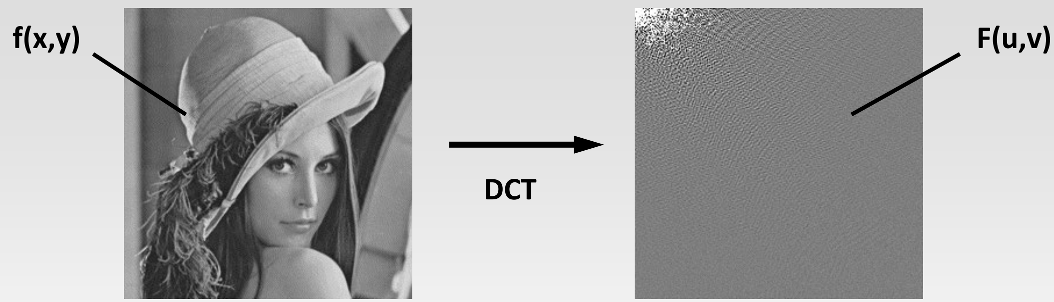
Undersampling: chrominance 8x



Discrete Cosine Transform (1)

For each 8x8 block, the ***Discrete Cosine Transform*** (***DCT***) is applied to break up the input signal into its different components.

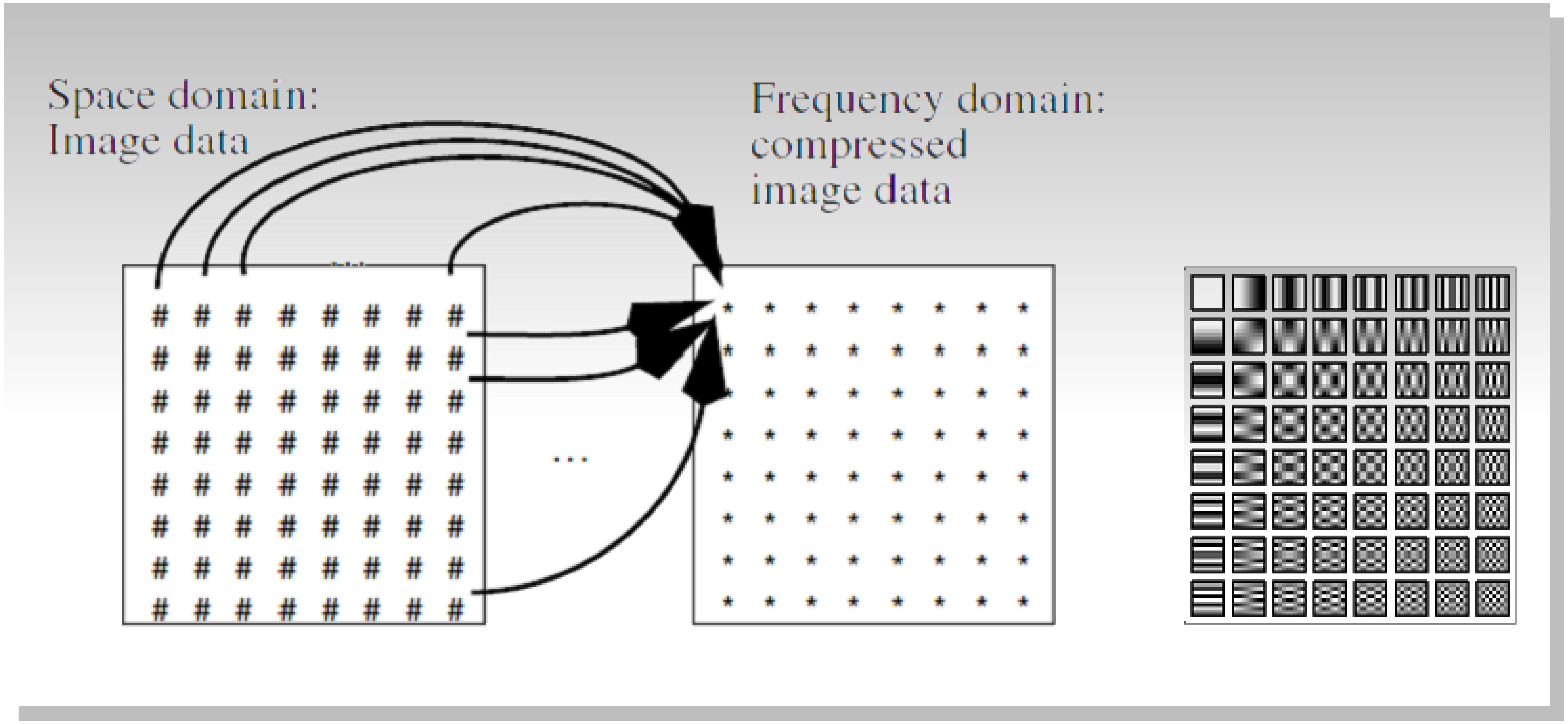
Each coefficient of the ***DCT*** defines the weight of the relative frequency inside the image.



$$F(u,v) = \alpha(u)\alpha(v)\sum_{x=0}^{N}\sum_{y=0}^{N} f(x,y)\cos\left[\frac{\pi(2x+1)u}{2N}\right]\cos\left[\frac{\pi(2y+1)u}{2N}\right]$$

Discrete Cosine Transform (2)

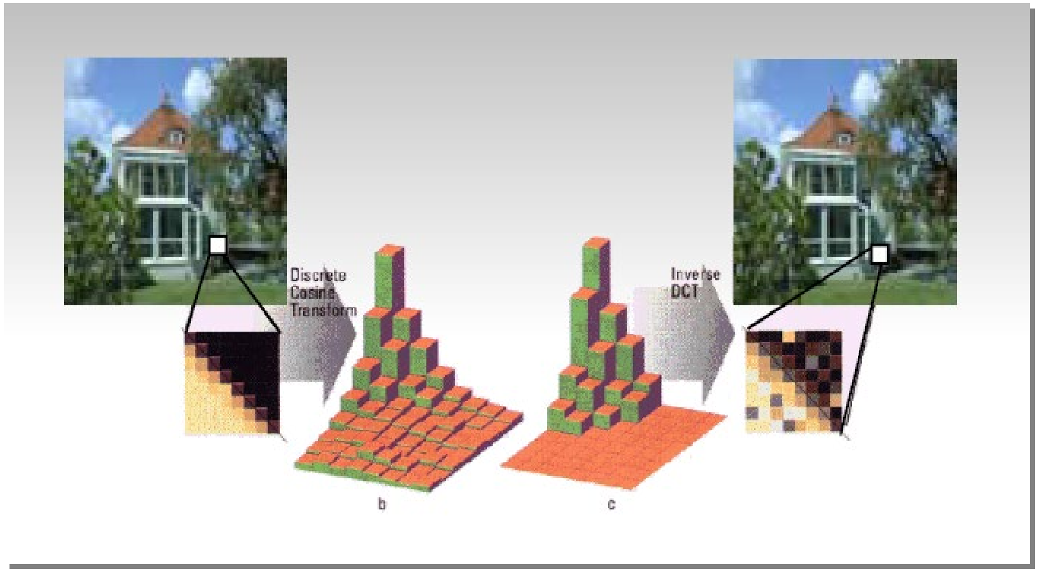
The element (0,0) contains the predominant color.



Quantization (1)

The DCT is invertible, hence the original image can be rebuilt

- DCT coefficient quantization causes the degradation of the restored image



DCT Coefficients

150	80	40	14	4	2	1	0
92	75	36	10	6	1	0	0
52	38	26	8	7	4	0	0
12	8	6	4	2	1	0	0
4	3	2	0	0	0	0	0
2	2	1	1	0	0	0	0
1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0

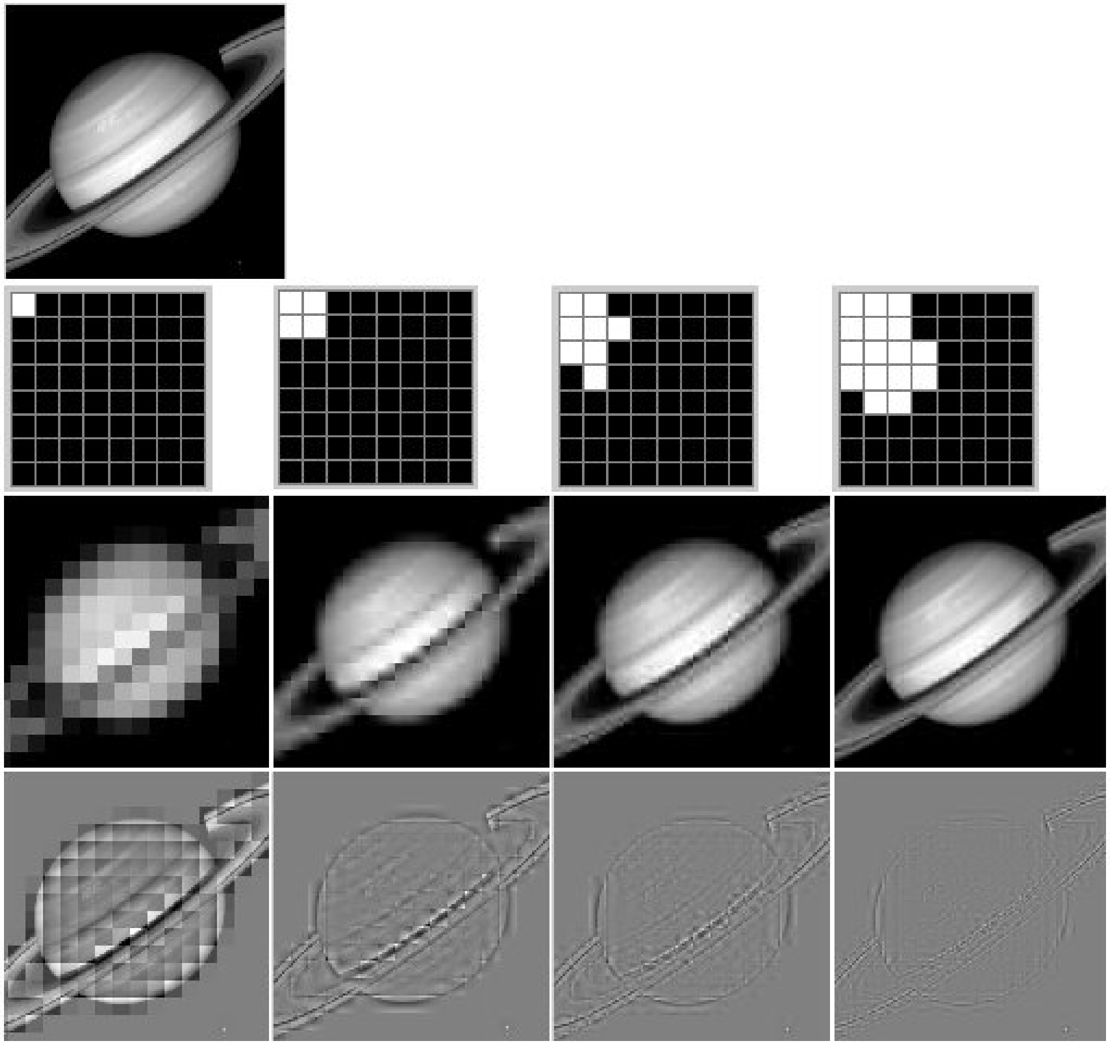
Quantized coefficients

150	80	20	4	1	0	0	0
92	75	18	3	1	0	0	0
26	19	13	2	1	0	0	0
3	2	2	1	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

Quantization table

1	1	2	4	8	16	32	64
1	1	2	4	8	16	32	64
2	2	2	4	8	16	32	64
4	4	4	4	8	16	32	64
8	8	8	8	8	16	32	64
16	16	16	16	16	16	32	64
32	32	32	32	32	32	32	64
64	64	64	64	64	64	64	64

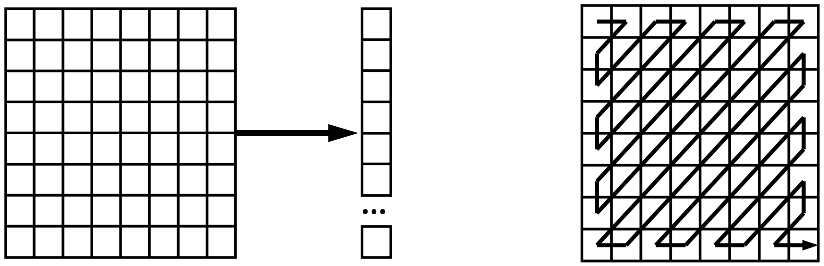
Quantization (2)



Linearization and coding of DCT coefficients

The highest frequencies represent details of the image that can be suppressed without losing noticeable information

- The 8x8 matrix with the DCT coefficients is linearized with a zig-zag scan
- Coefficients of the highest frequencies are negligible or null
- It is possible to use RLE compression techniques



JPEG compression

The JPEG compression has four different encoding methods

- *Sequential* coding: each image is encoded with one single scan from top to bottom left to right
- *lossless* coding: uses predictive techniques, not the DCT. Each point is represented as the difference to the expected value based on adjacent points.

JPEG compression

The JPEG compression has four different coding methods

- *Sequential* coding: each image is encoded with one single scan from top to bottom left to right.
- *lossless* coding: uses predictive techniques, not the DCT. Each point is represented as the difference to the expected value based on adjacent points.
- *Progressive* coding: allows to show the image with low quality at the beginning, and progressively with increasing quality.

JPEG Progressive

Progressive JPEG can be developed with one of the following algorithm:

Spectral selection:

Scan 1: encoding of DC elements + few AC (example: AC1, AC2)

Scan 2: encoding of some of the remaining AC (example: AC3, AC4, AC5)

…

Scan k: encoding of the last AC (example: AC61, AC62, AC63)

Consecutive approximations:

Scan 1: encoding of few more significant bit (MSB), for example bit 7, 6, 5, and 4

Scan 2: encoding of some of the remaining bit, for example bit 3

…

Scan k: encoding of the least significant bit, the bit 0

JPEG compression

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The JPEG compression has four different coding methods

- *Sequential* coding: each image is encoded with one single scan from top to bottom left to right.
- *lossless* coding: uses predictive techniques, not the DCT. Each point is represented as the difference to the expected value based on adjacent points.
- *Progressive* coding: allows to show the image with low quality at the beginning, and progressively with increasing quality.
- *hierarchical* coding: the image is undersampled and JPEG coded, and then the differences between the rebuild image and the original one is coded

Hierarchical JPEG Algorithm

1. Resolution reduction of the image by a factor 2 (f_2) for two times (f_4)
2. F_4 compression using one of the other JPEG methods
3. Compression of the differences between f_4 and f_2 coding using one of the other JPEG methods
4. Compression of the differences between f_2 coding and the original image using one of the other JPEG methods

JPEG: why & when

Photographic images full of colors and shades

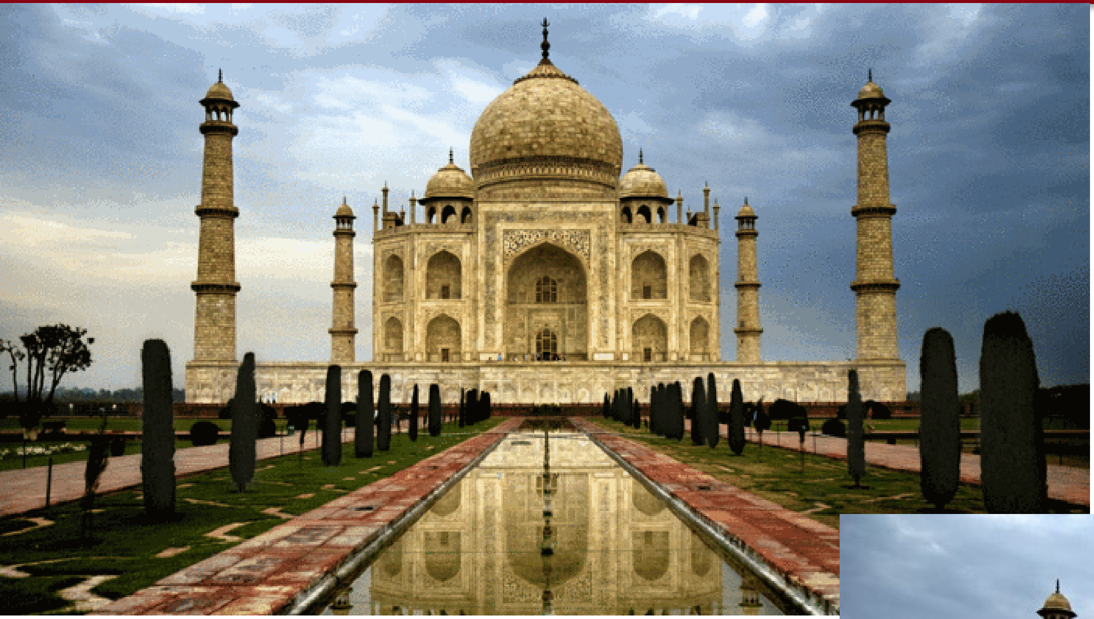
Precise representation of minor details is not essential

Loading and visualization can be progressive

Possibility to regulate the quality of the image for visualization or printing

Most used compression standard

Comparison: colors



GIF Format

PNG Format

Comparison: animations

GIF Format

PNG Format

Comparisong: size

JPEG format

PNG Format

Resolution:
1200x600

Size:
476 KB

Size:
2551 KB

JPEG Limitations

JPEG 2000

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It is the last compression standard for image distribution over Web and smartphones

It is not intended to substitute JPEG format but to begin a gradual transition (it may require a specific plug-in)

Strongly oriented to transmission: an image of 34,6 KB at a transmission speed of 19,2 Kbps requires 14,4 s for download.
JPEG 2000 makes the image visible in 1,2 s

Main features - 1

It uses a Discrete Wavelet Transform (DWT) that provides an encoding that supports multiresolution without data redundancy, with both lossy or lossless encoding.

Supports lower bitrates than the JPEG standard

Supports different compression modalities and color spaces

Allows up to 256 information channels (satellite images)

Supports ROI encoding (Region of Interest)

Supports data transmission in disturbed environments

Main features - 2

It is an open standard for further implementation that allows metadata insertion in the file header.

Supports images bigger than 64kx64k pixel (> 4GB)

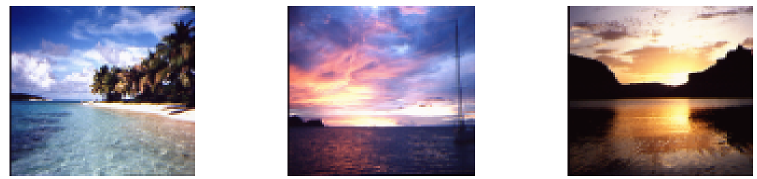
Works well with both natural and artificial images

Support for Watermarking (Copyright)

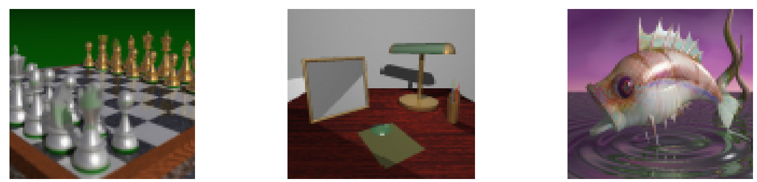
Allows two different compression systems:

- DCT: only for compatibility with JPEG
- Wavelet: allows all new features

Examples



(a)



(b)

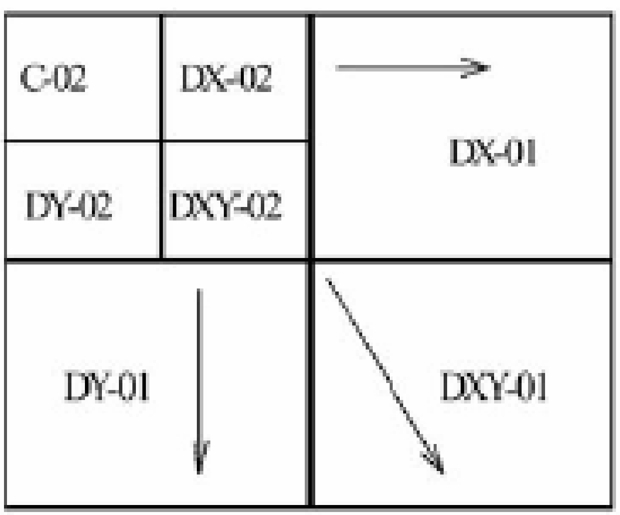
(c)

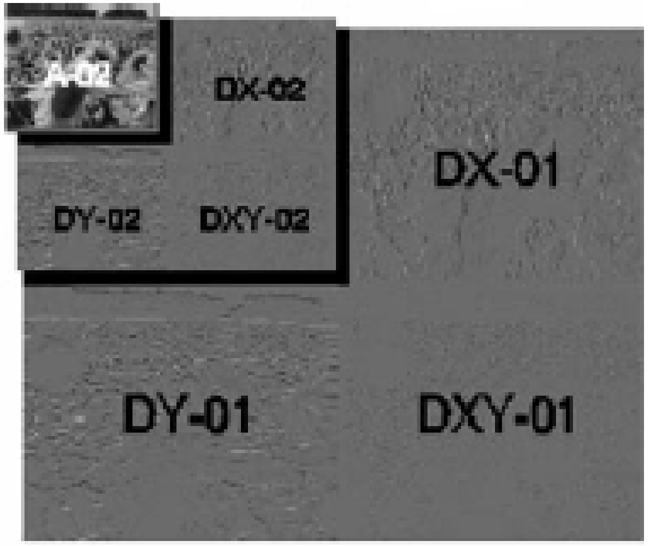
Test images used for JPEG/JPEG2000 performance evaluation (a): Natural images. (b): Computer generated images. (c): Medical images.

Discrete Wavelet Transform

Each color component of the image is elaborated independently, producing 4 regions (*tiles*), such that each tile dimension is half of the original image. The same procedure is repeated several times.

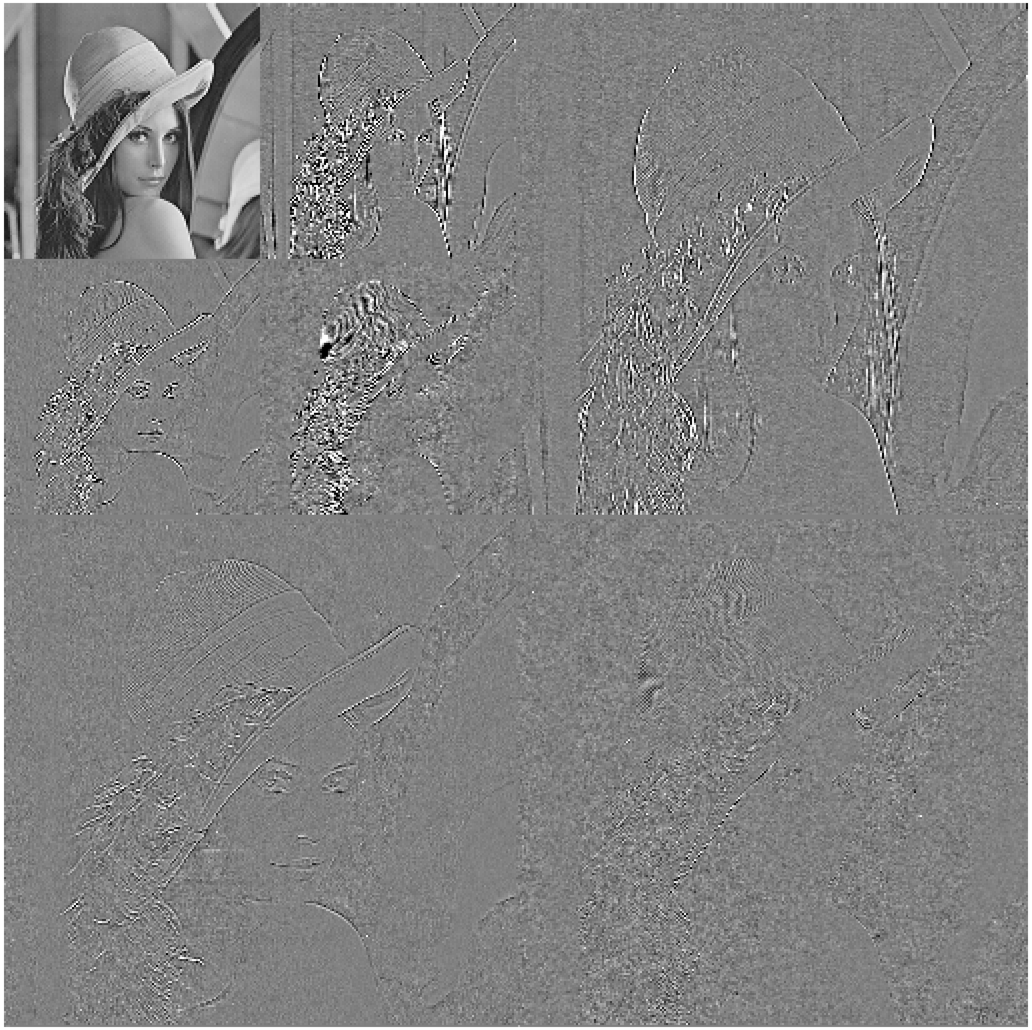
On the first quadrant, there are the low frequencies; on the others, the high ones.



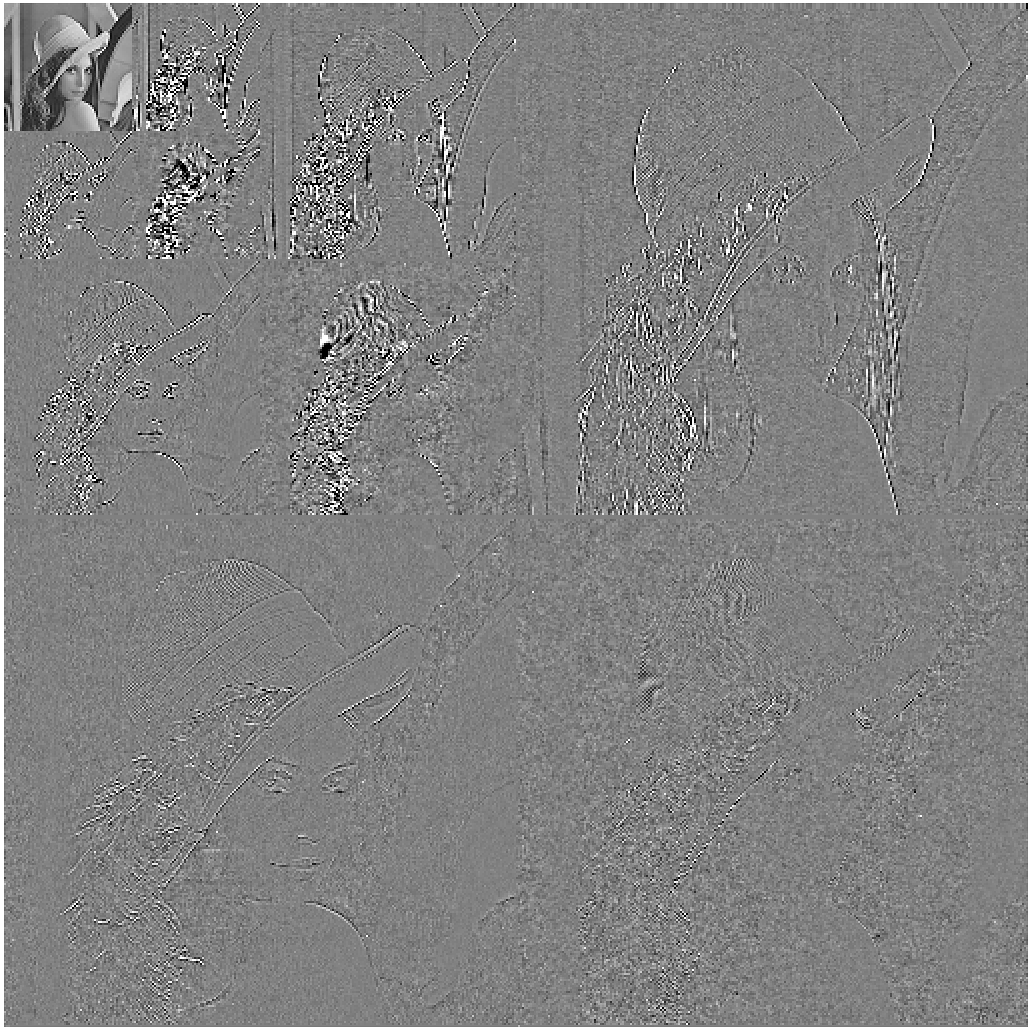


Wavelet decomposition

Wavelet decomposition

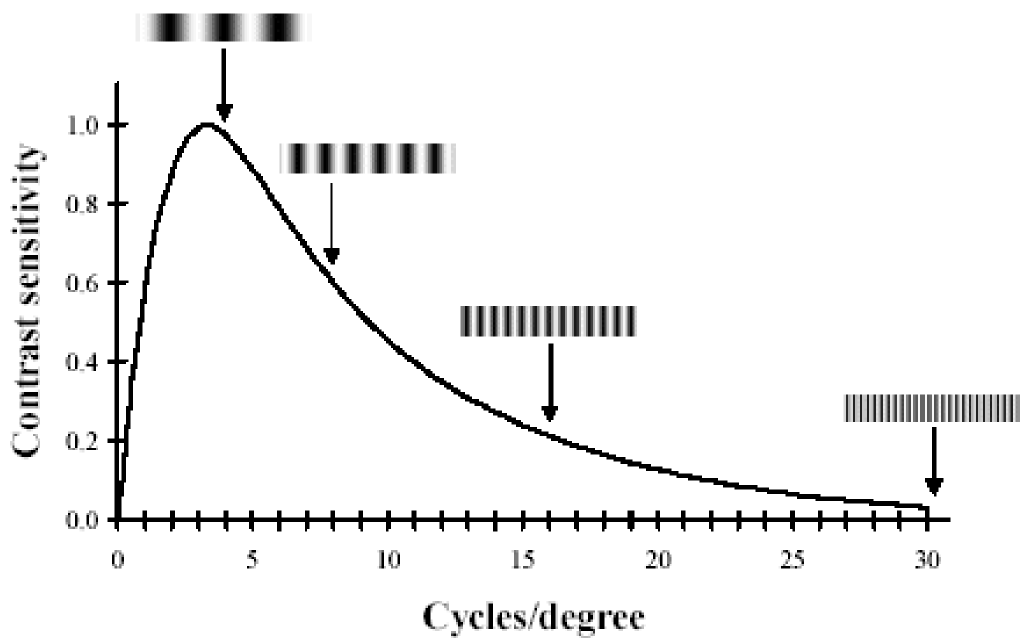


Wavelet decomposition

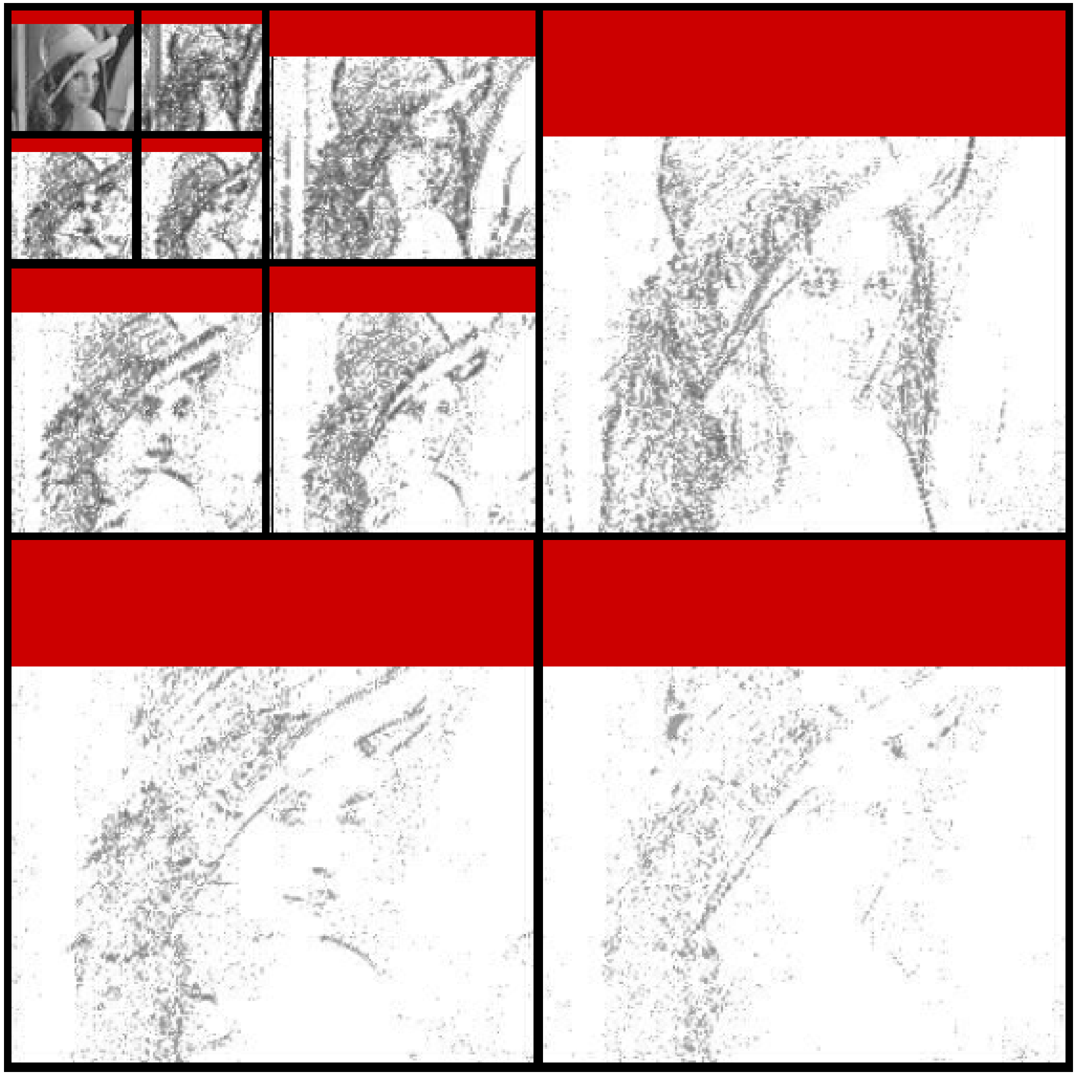


JPEG2000 Quantization

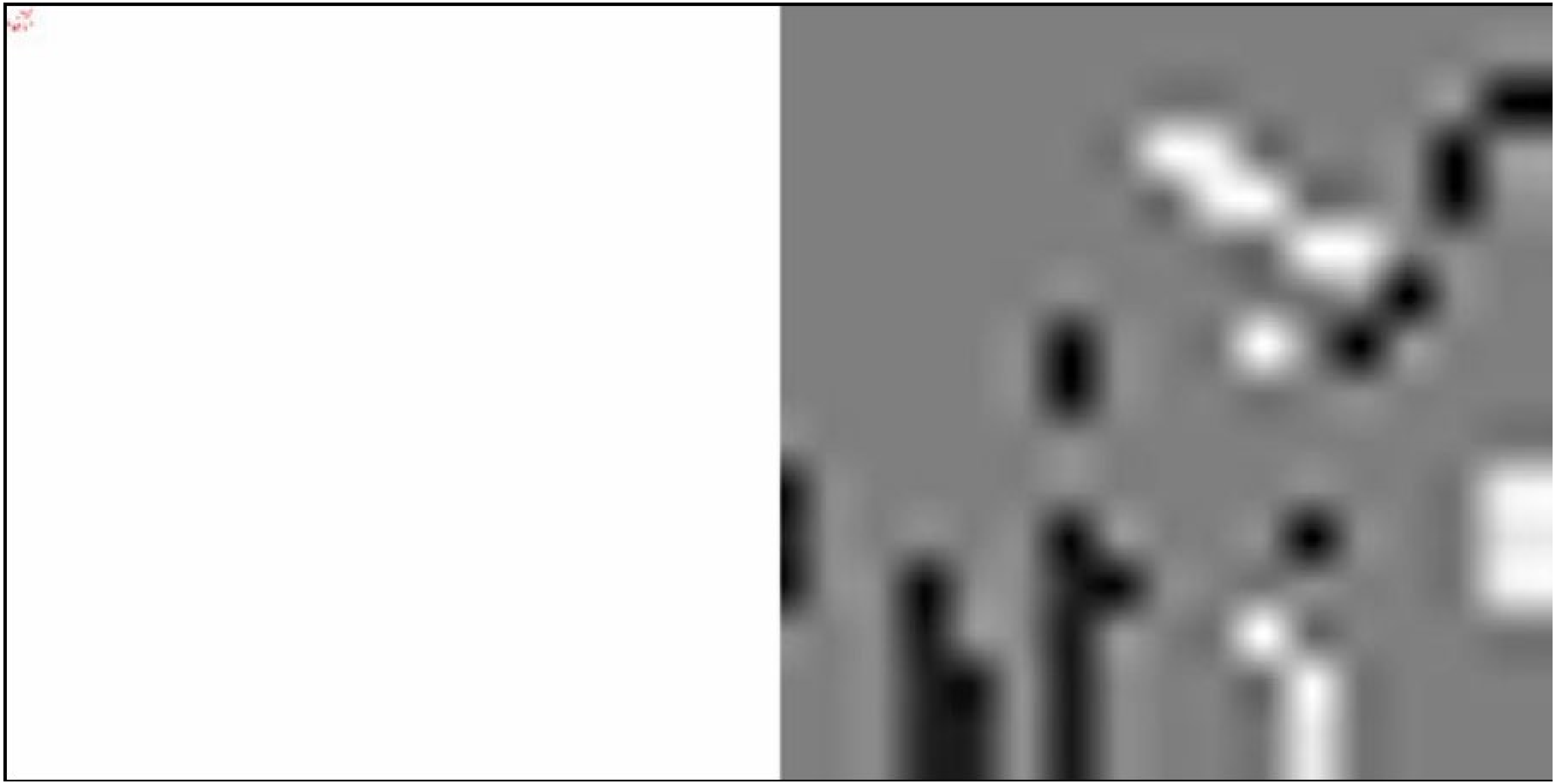
It is possible to draw a diagram of the human eye sensibility over contrast variation. The quantization coefficients are defined based on the sensibility to the associated sub-band.



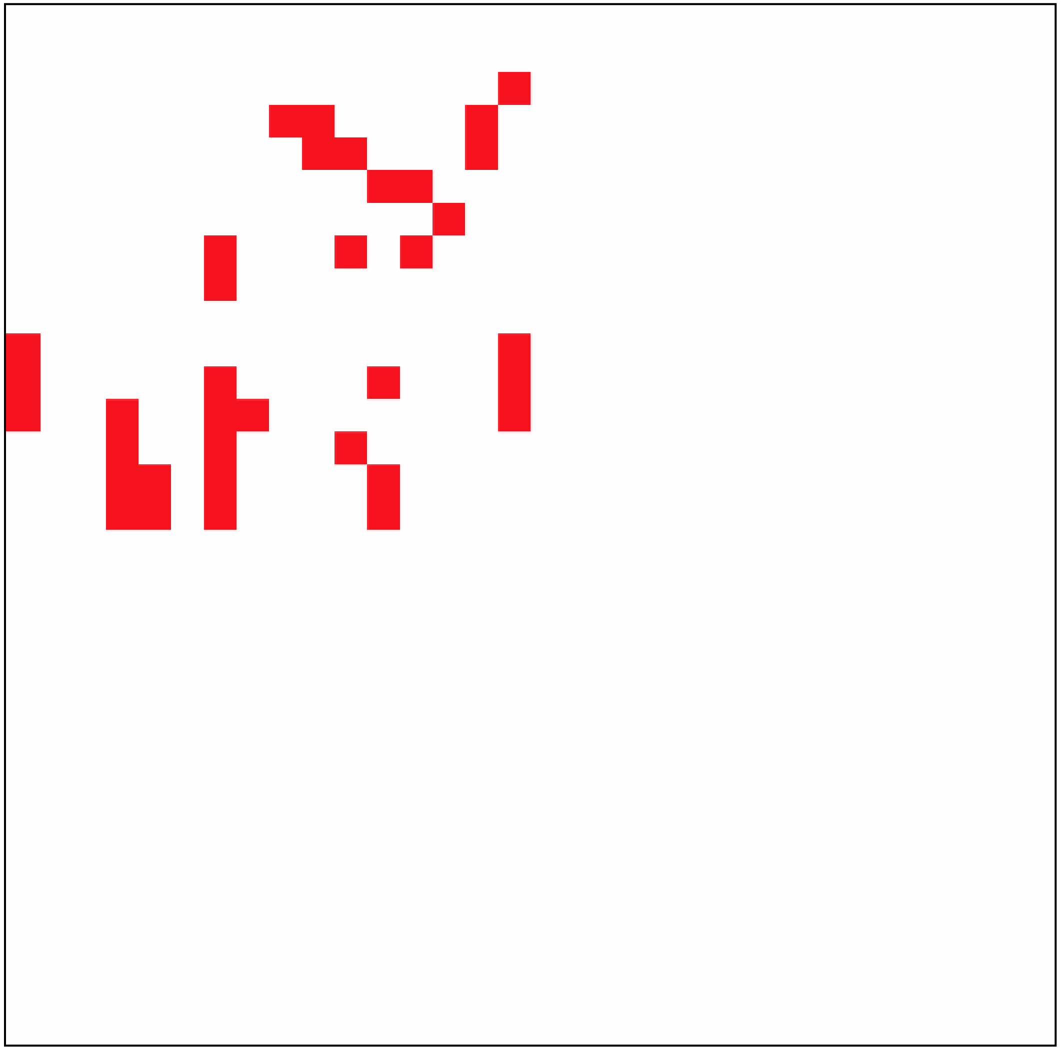
Decoding and random access



Decoding



Decoding



Decoding

Decoding

Decoding

Decoding

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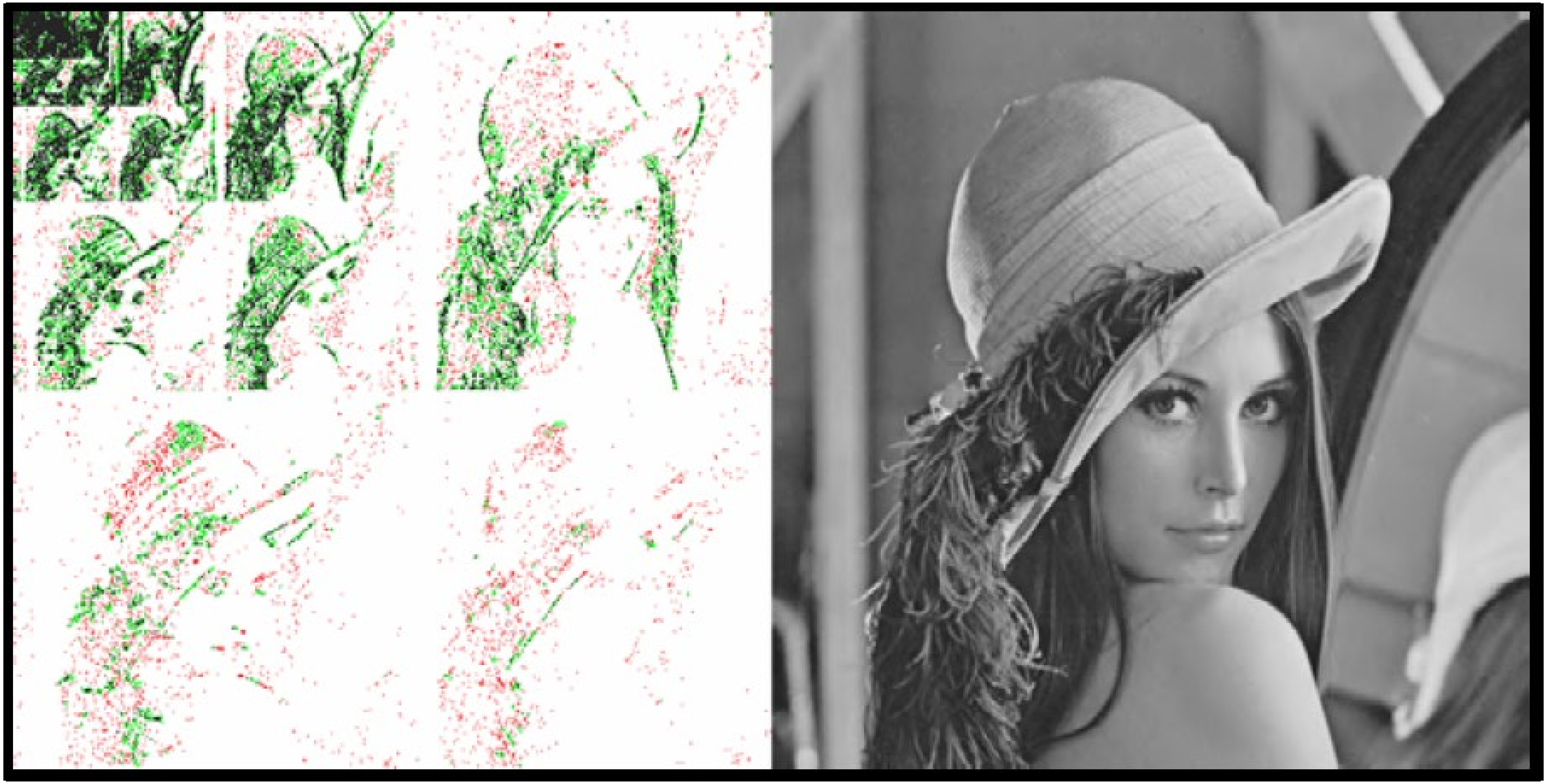
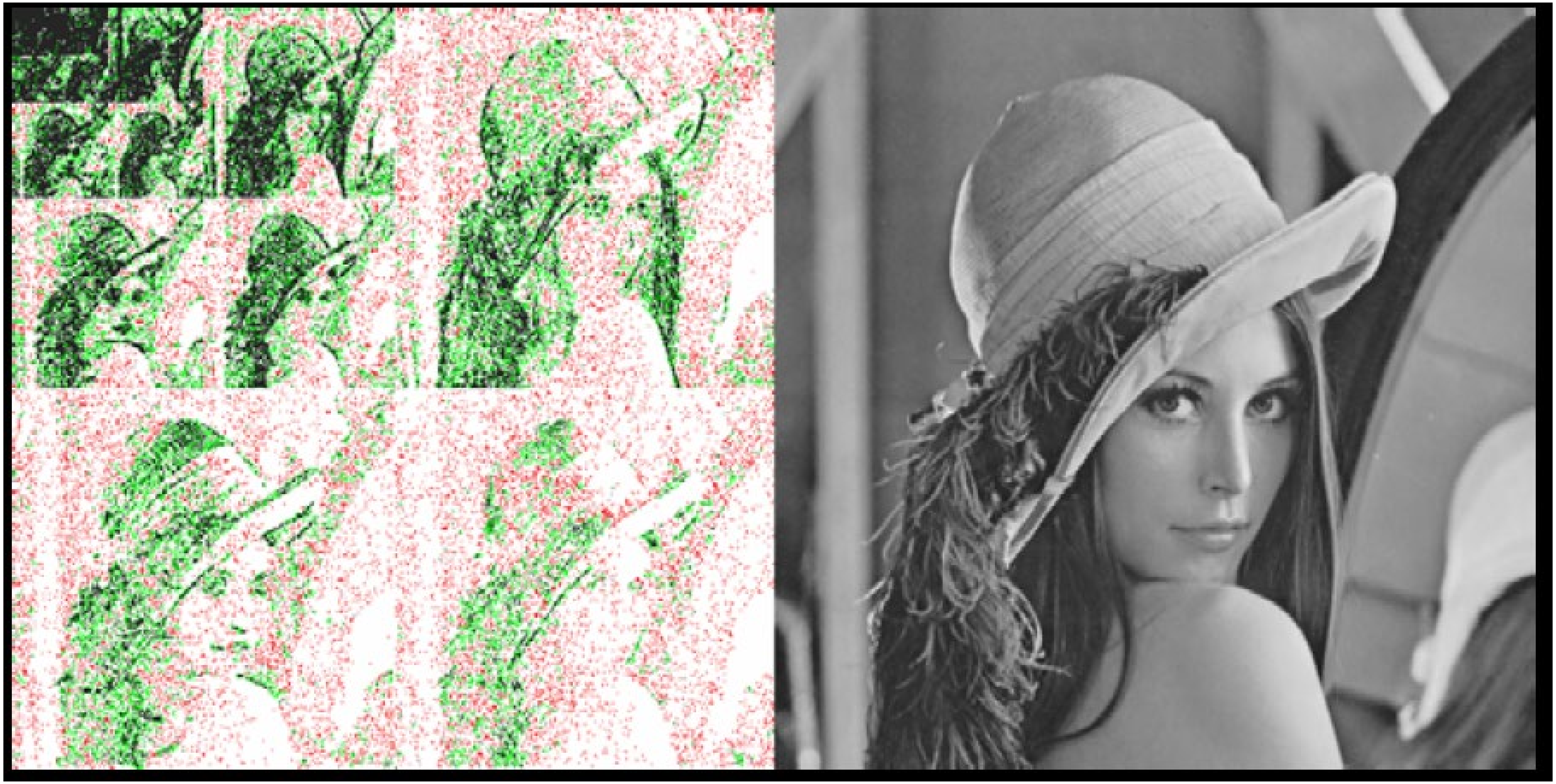
Decoding

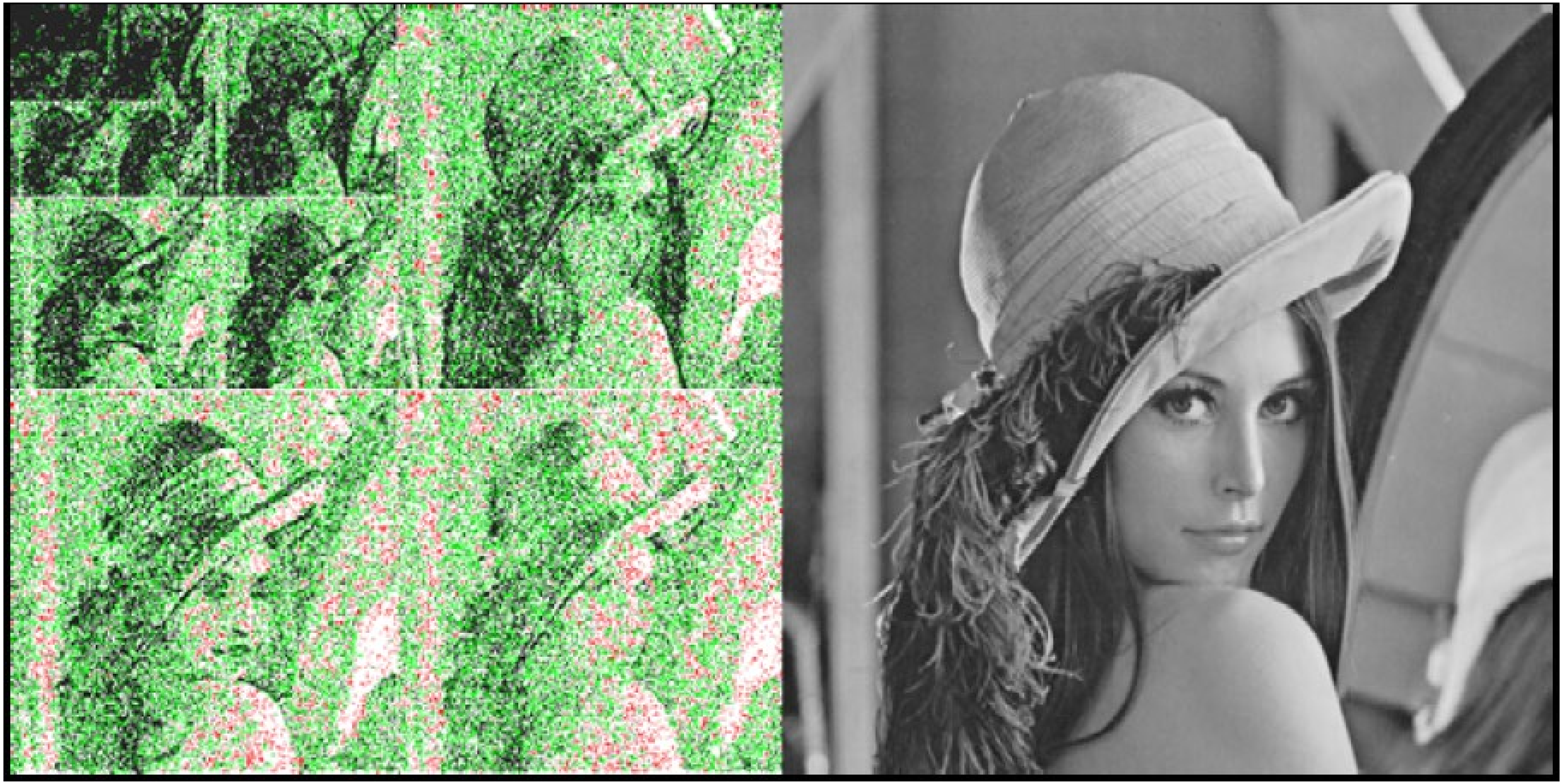
Decoding



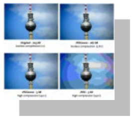
Decoding

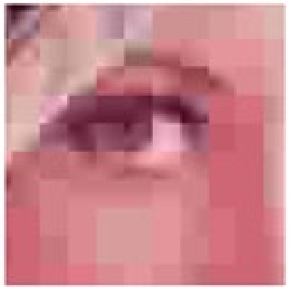


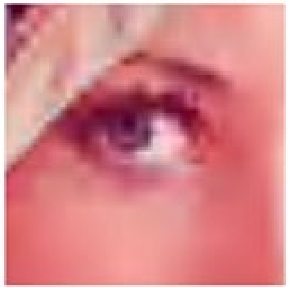
Decoding



JPEG vs JPEG2000







ROI: Region of Interest

It is a special technique that isolates an important image area and encodes it with higher quality than the rest of the image (usually the background).

The method is called MAXSHIFT and is based on shifting coefficients related to the ROI to the highest bitplanes.

ROI: example

Errors tolerance (1)

Bit error rate = 10^{-5}

JPEG 16:1 CR

JPEG 2000 16:1 CR

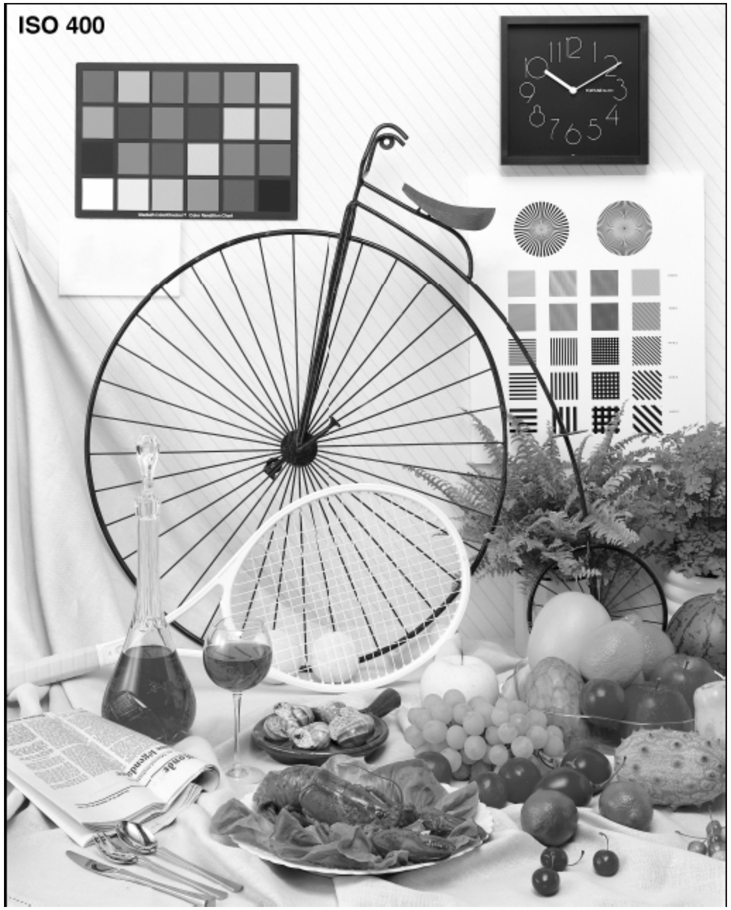
Errors tolerance (2)

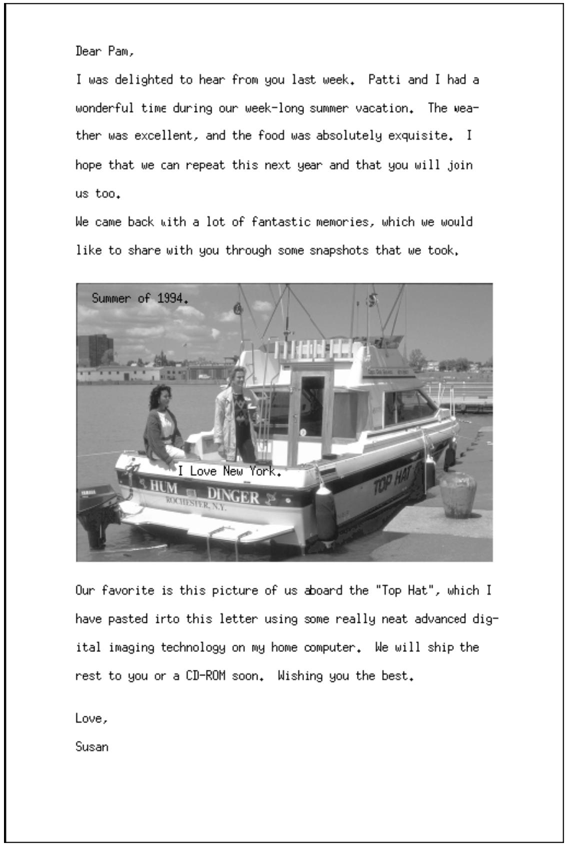
Bit error rate = 10^{-4}

JPEG 16:1 CR

JPEG 2000 16:1 CR

JPEG2000: test images (1)





Dear Pam,

I was delighted to hear from you last week. Patti and I had a wonderful time during our week-long summer vacation. The wea- ther was excellent, and the food was absolutely exquisite. I hope that we can repeat this next year and that you will join us too.

We came back with a lot of fantastic memories, which we would like to share with you through some snapshots that we took.

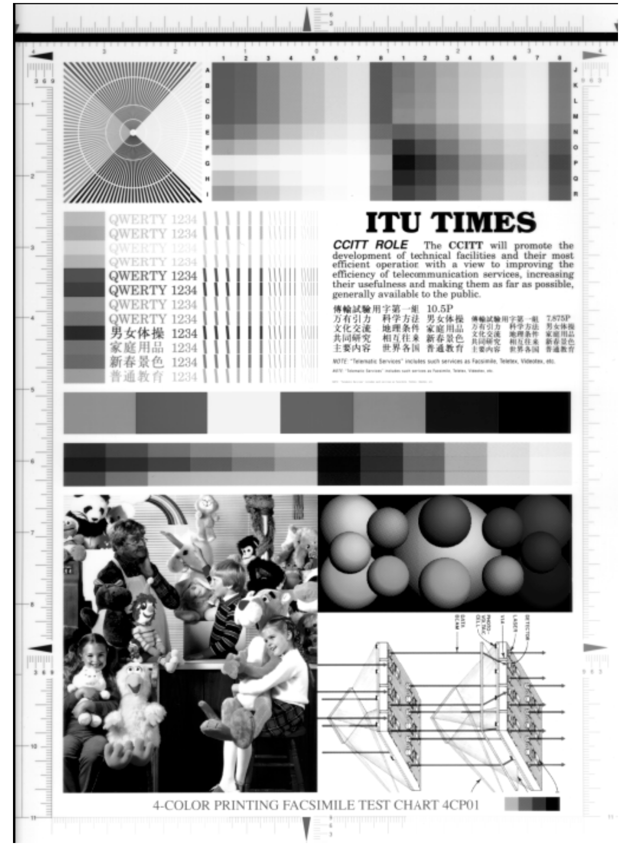
Summer of 1994.

I Love New York.

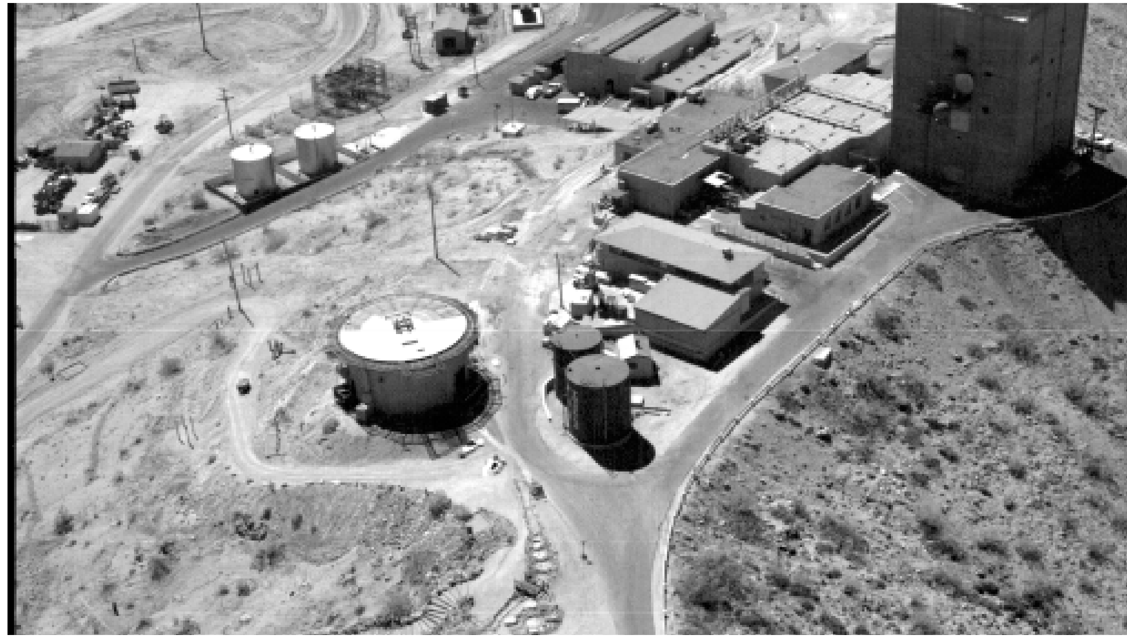
Our favorite is this picture of us aboard the "Top Hat", which I have pasted irto this letter using some really neat advanced dig- ital imaging technology on my home computer. We will ship the rest to you or a CD-ROM soon. Wishing you the best.

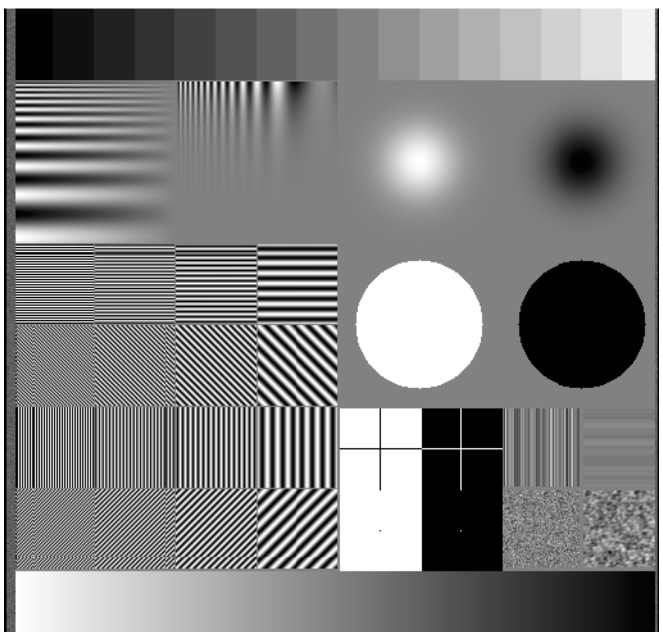
Love,

Susan



JPEG2000: test images (2)





JPEG2000: test images (3)

Learning Material JPEG2000

Official site:

- http://www.jpeg.org/

Additional material

- http://www.di.uniba.it/~laura/JPEG2000/JPEG2000.htm

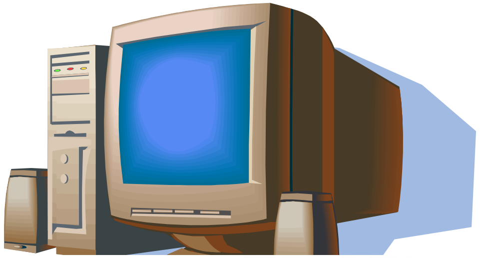
Vector graphics

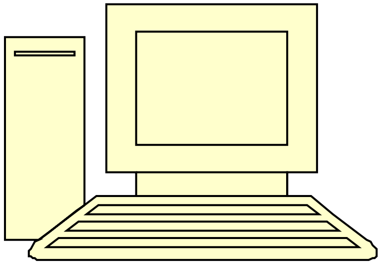
Pictorial images are represented as matrixes of points (*pixel*); at each point, a color is associated.

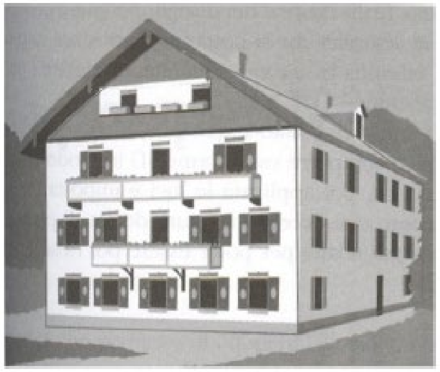
Vector graphics are described using ***geometrical formulas*** (lines, curves, polygons…) that define ***shapes***, *color fills,* and *positioning* using only a mathematical point-of-view.

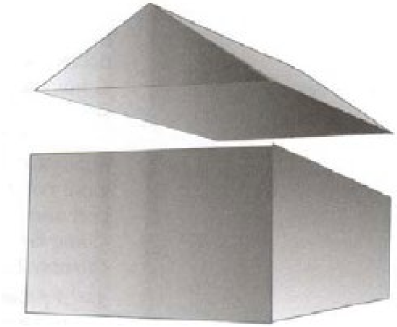
Pictorial images need to be acquired; artificial images are the result of elaboration from the calculator

Examples









Characteristics of vector graphics

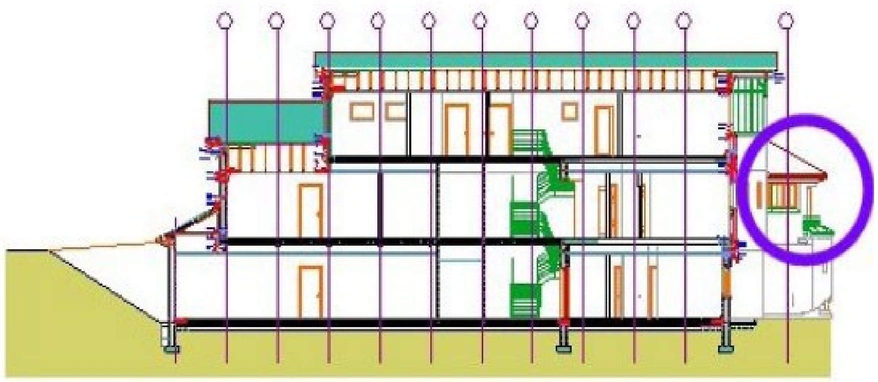
High precision for detailed draws

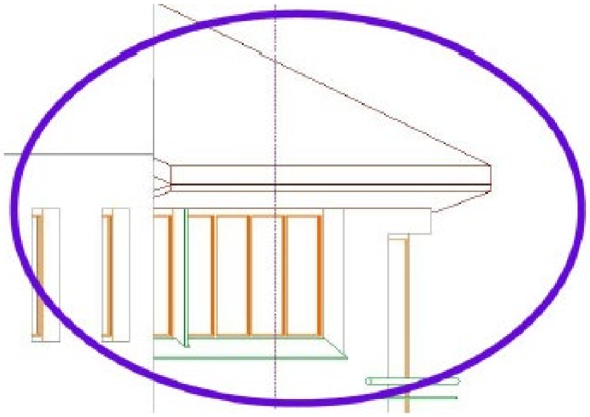
Quality is independent of pixel

Compact dimension

Details enlargement without quality loss (*scalability*)

Easy to manipulate





Vector graphics: why & when

For graphics and paper advertisement because easily editable and scalable

For urban and construction design and for industrial design (3D graphics)

Typography (Typeface description)

Animation (videogames)

[http://www.redstudio.it/]