Multimedia Computing

Image Representation and Fundamentals

One picture is more than ten thousand words ……

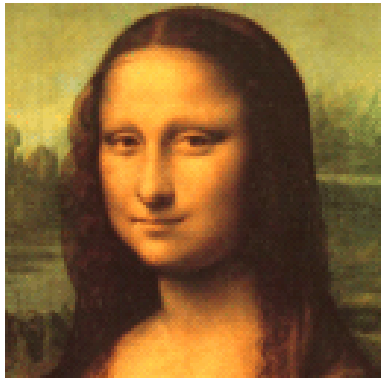
What is a digital image?

- Image:

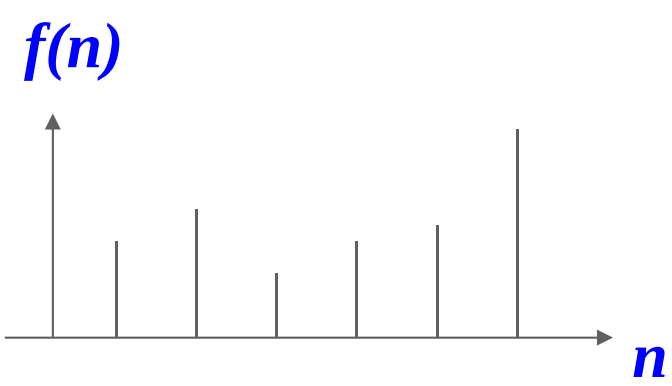
  A two-dimensional function $f(x,y)$ where (x, y) are spatial coordinates and the amplitude f is called the intensity or gray level.

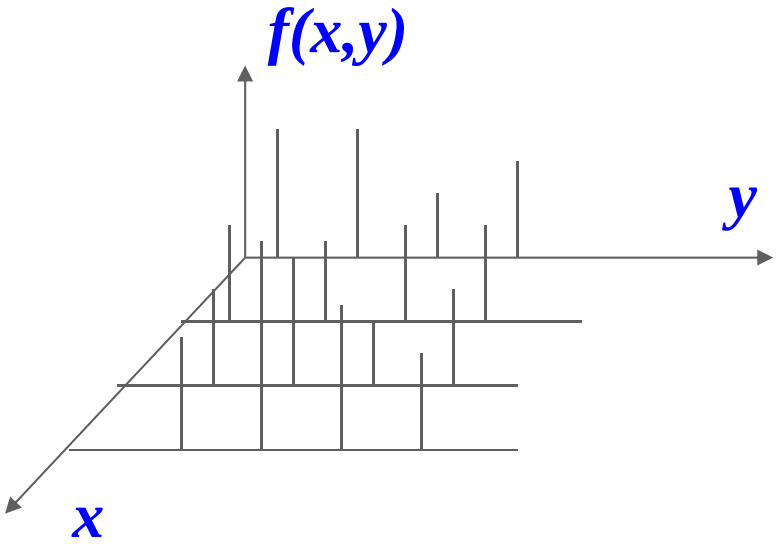
- When x, y and f are discrete quantities, the image is called a digital image.





Digital image representation

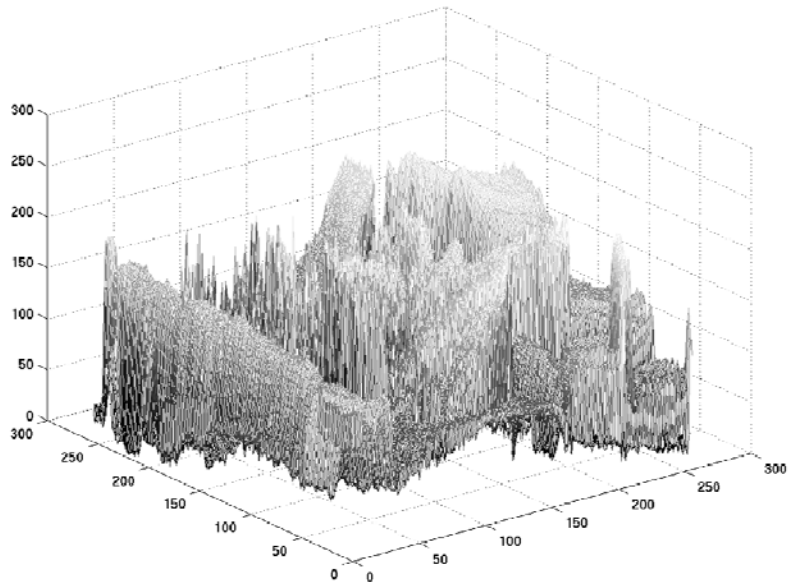




$$f = \begin{bmatrix} 5 \\ 6 \\ 12 \\ 34 \\ 5 \\ 11 \end{bmatrix}$$

$$f = \begin{bmatrix} 1 & 3 & 4 & 5 \\ 6 & 7 & 19 & 20 \\ 11 & 13 & 41 & 23 \\ 55 & 21 & 11 & 57 \end{bmatrix}$$

Show a digital image



Origin of digital image processing

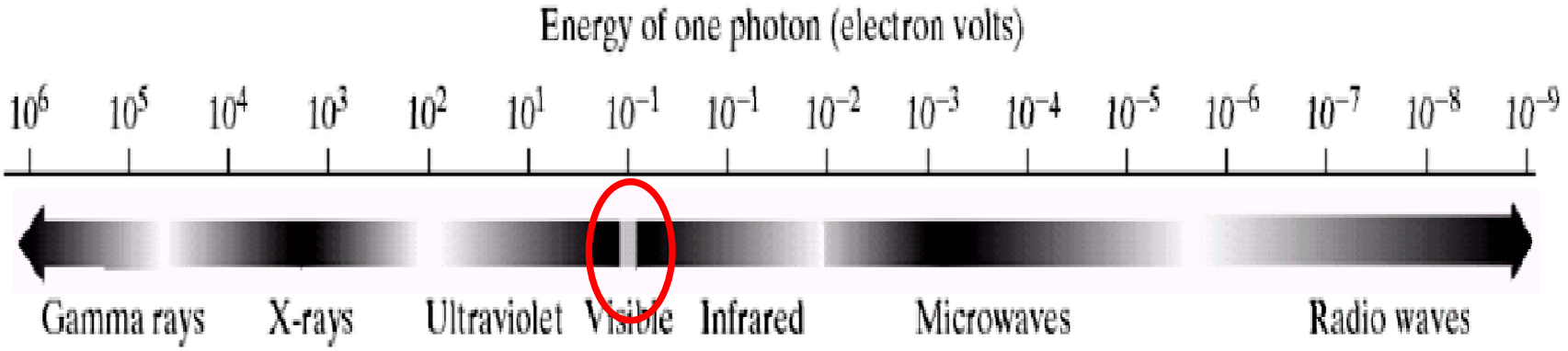
- In 1920s, pictures were first sent by submarine cable between London and New York.

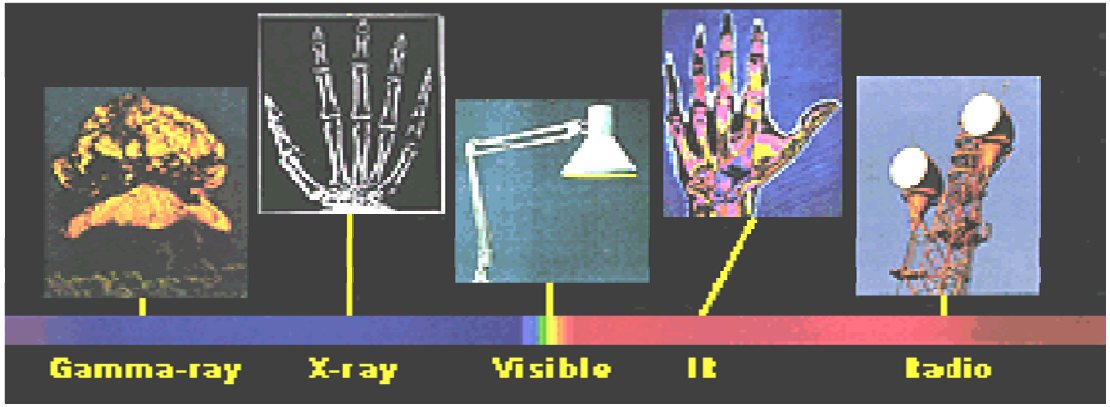
A digital picture produced in 1921 from a coded tape by a telegraph printer.

Modalities in digital imaging

- According to the sources of images, we can categorize imaging modalities into:
  - Electromagnetic (EM) energy spectrum
  - Acoustic, ultrasound
  - Computer generated images

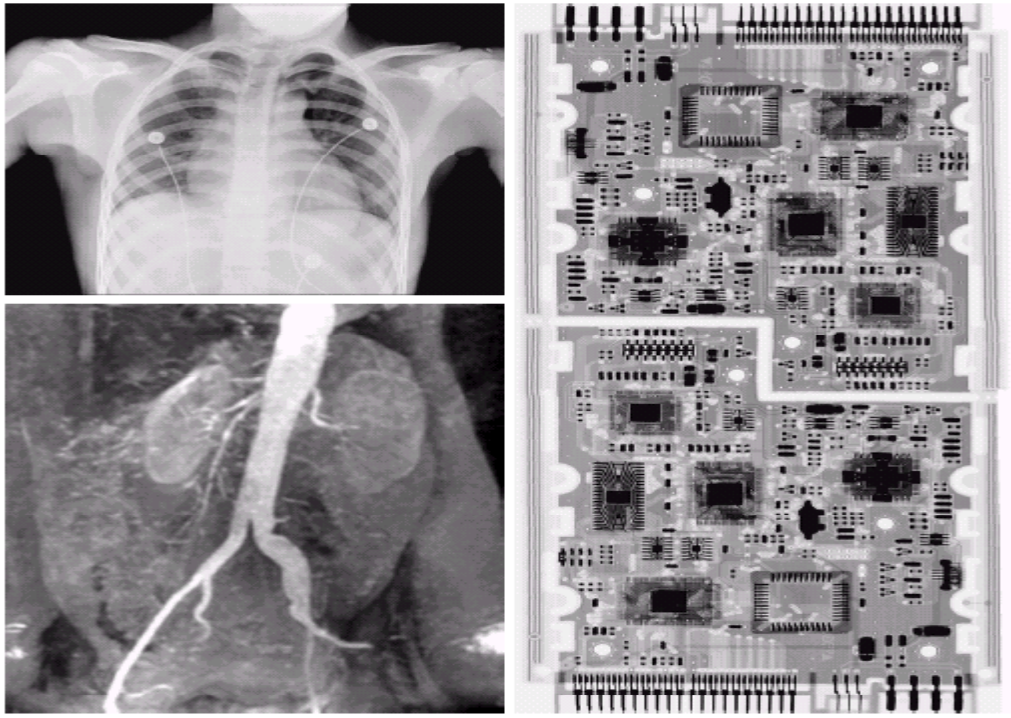
Electromagnetic (EM) spectrum images





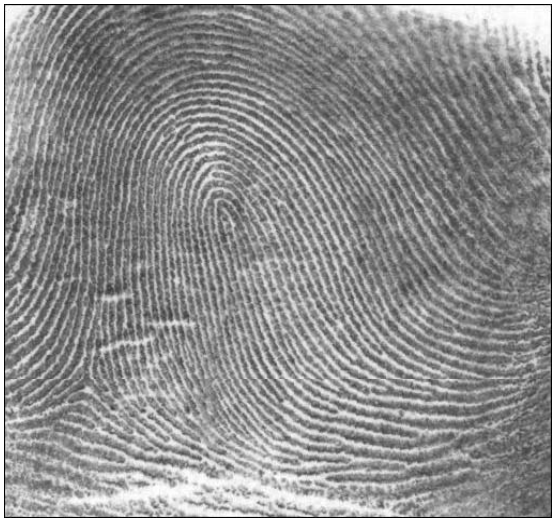
EM spectrum image: example

- X-ray imaging
  - X-rays are used extensively in medical imaging and in industry.



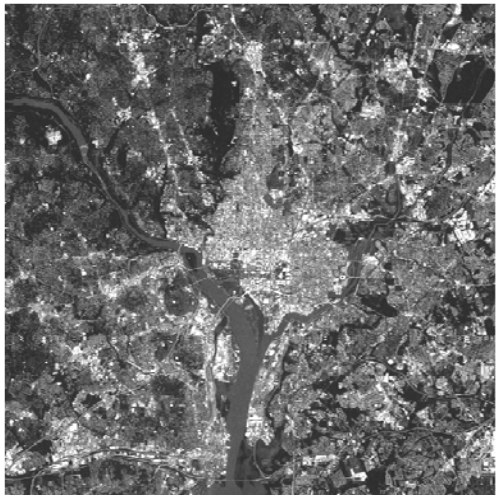
EM spectrum image: example

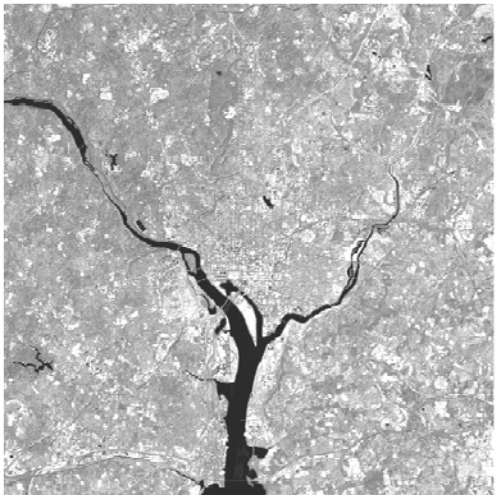
- Imaging in visible band
  - Biometrics: fingerprint recognition
  - Automated license plate reading



EM spectrum image: example

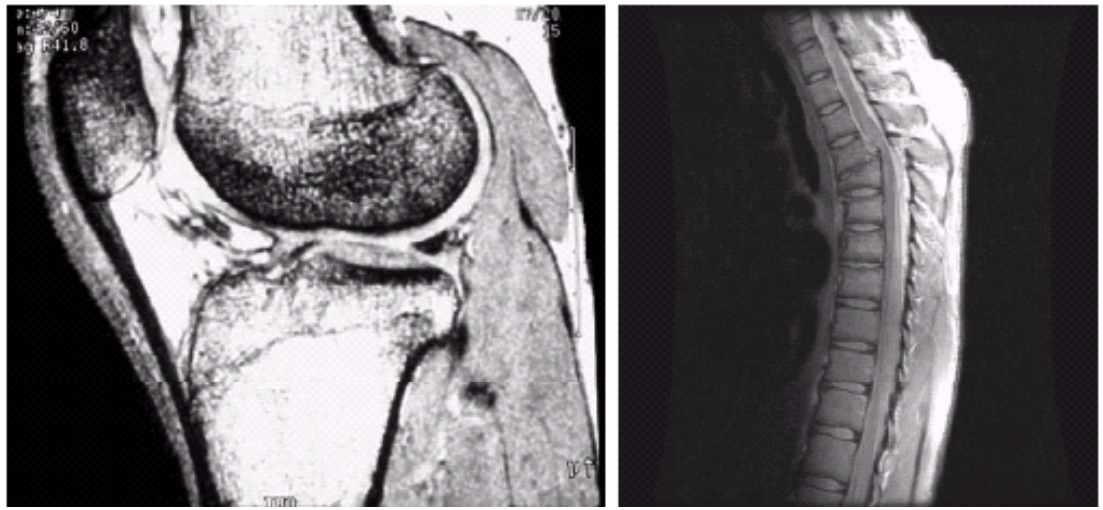
- Imaging in visible and infrared band
  - Remote sensing: to obtain images of Earth from space for purposes of monitoring
  - Usually a scene is imaged in several bands





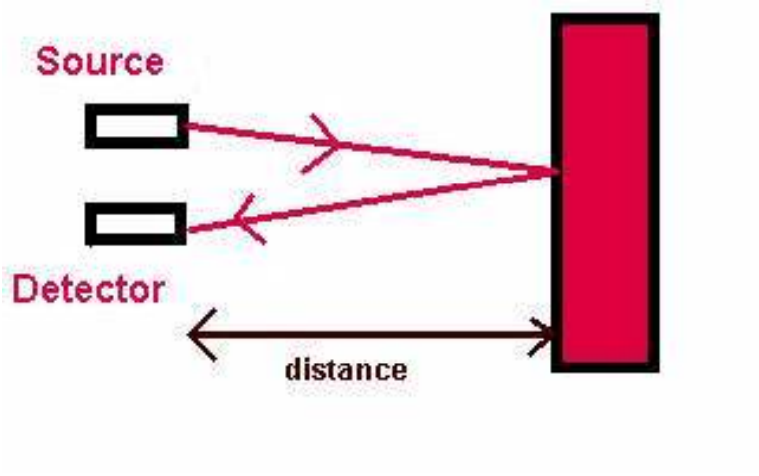
EM spectrum image: example

- Imaging in radio band
  - Magnetic Resonance Imaging (MRI): The patient is placed in a powerful magnet. Radio waves are passed through his/her body in short pulses



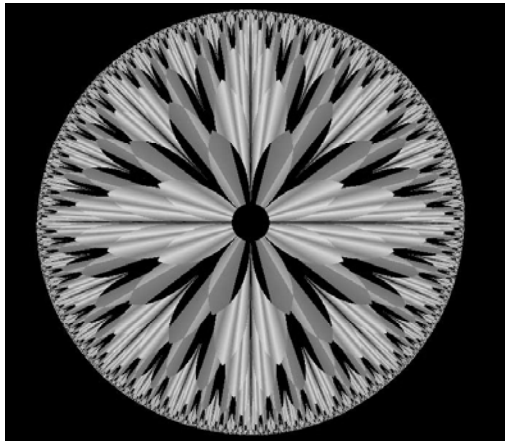
Other imaging modalities

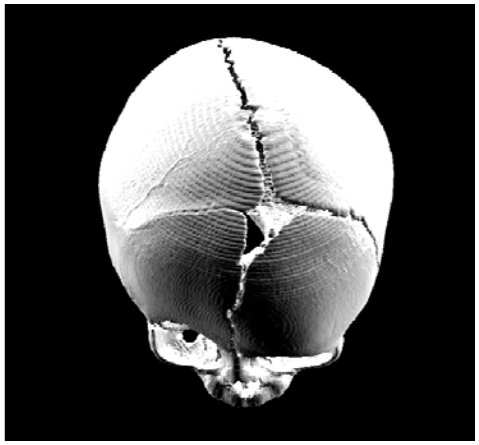
- Acoustic Imaging
  - Ultrasound system transmits high-frequency (1 to 5 MHz) sound pulses into the body.



Other imaging modalities

- Computer generated Images
  - Fractals are examples of computer generated images.
  - 3-D modeling is another example.





Just for fun ☺

- Count the black dots

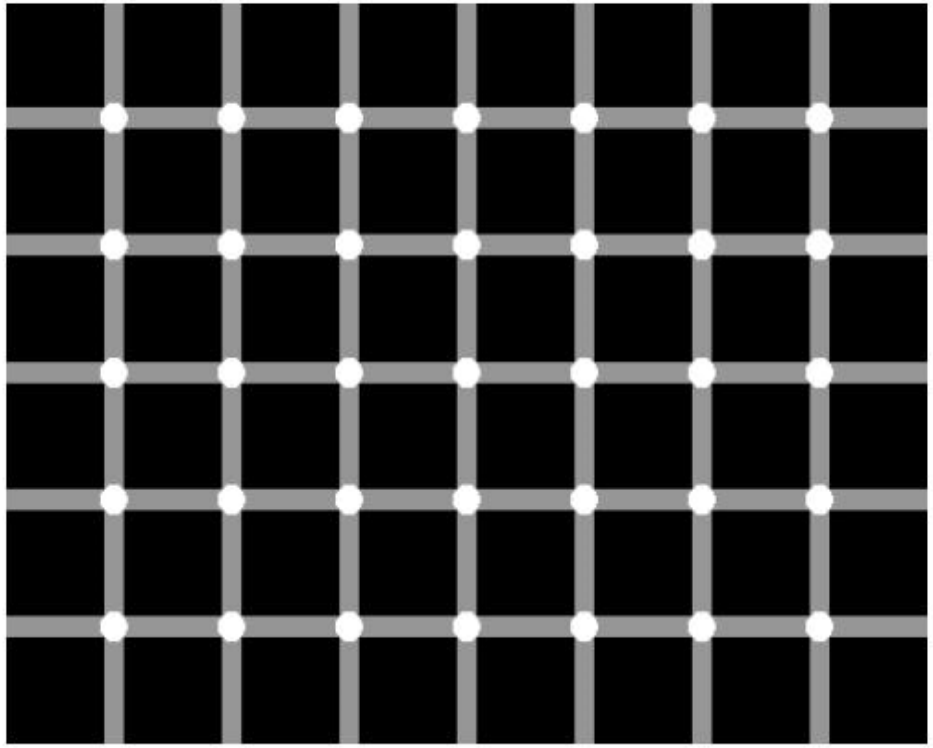


Image sensing and acquisition

- Image is generated by energy of the illumination source reflected (natural scenes) or transmitted through objects (e.g. X-ray).
- A sensor detects the energy and converts it to electrical signals.
- Sensor should have a material that is responsive to the particular type of energy being detected.

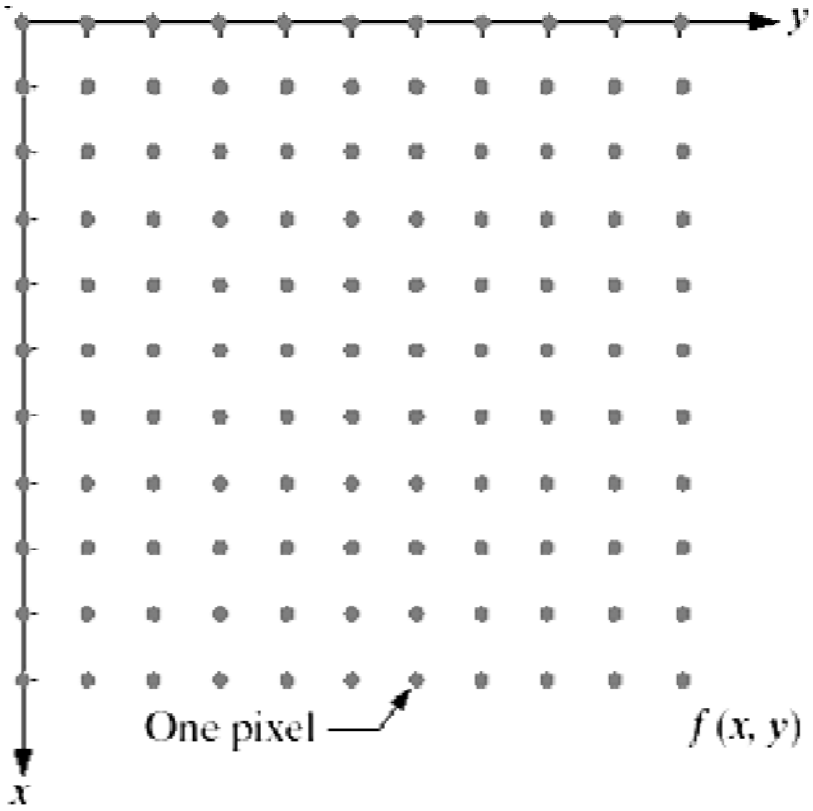
Sampling & Quantization

- Computer processing:

  image ***f(x,y)*** must be digitized both spatially and in amplitude
- Sampling → digitization in spatial coordinates
- Quantization → digitization in amplitude
- An image will be represented as a matrix

  $[f(i,j)]_{NxM}$ with $i=1:N;\ j=1:M;\ f \in [0, G]$.
- Normally, we set: $N=2^n$, $M=2^m$, $G=2^k$

Sampling & Quantization

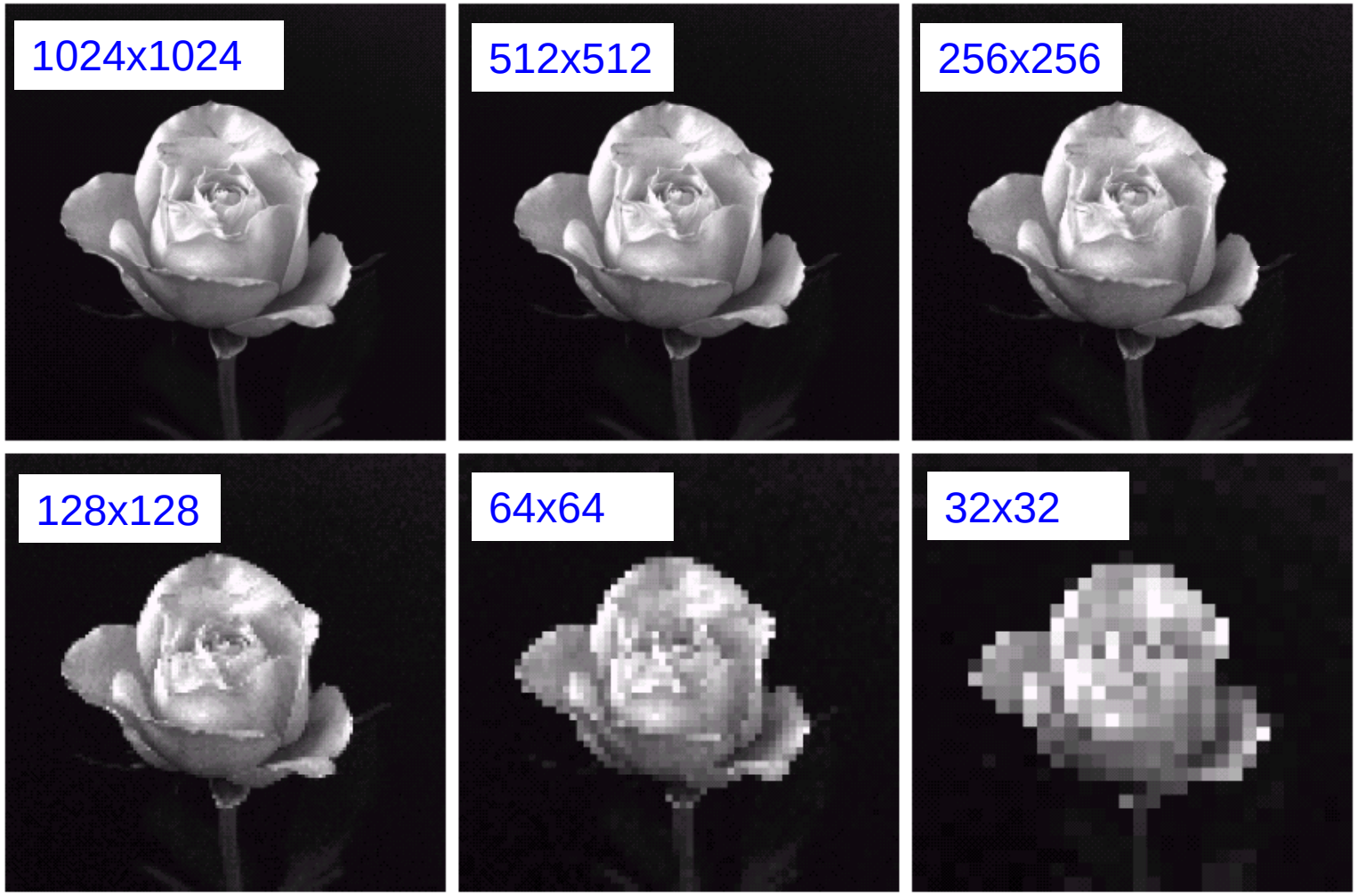


Sampling & Quantization

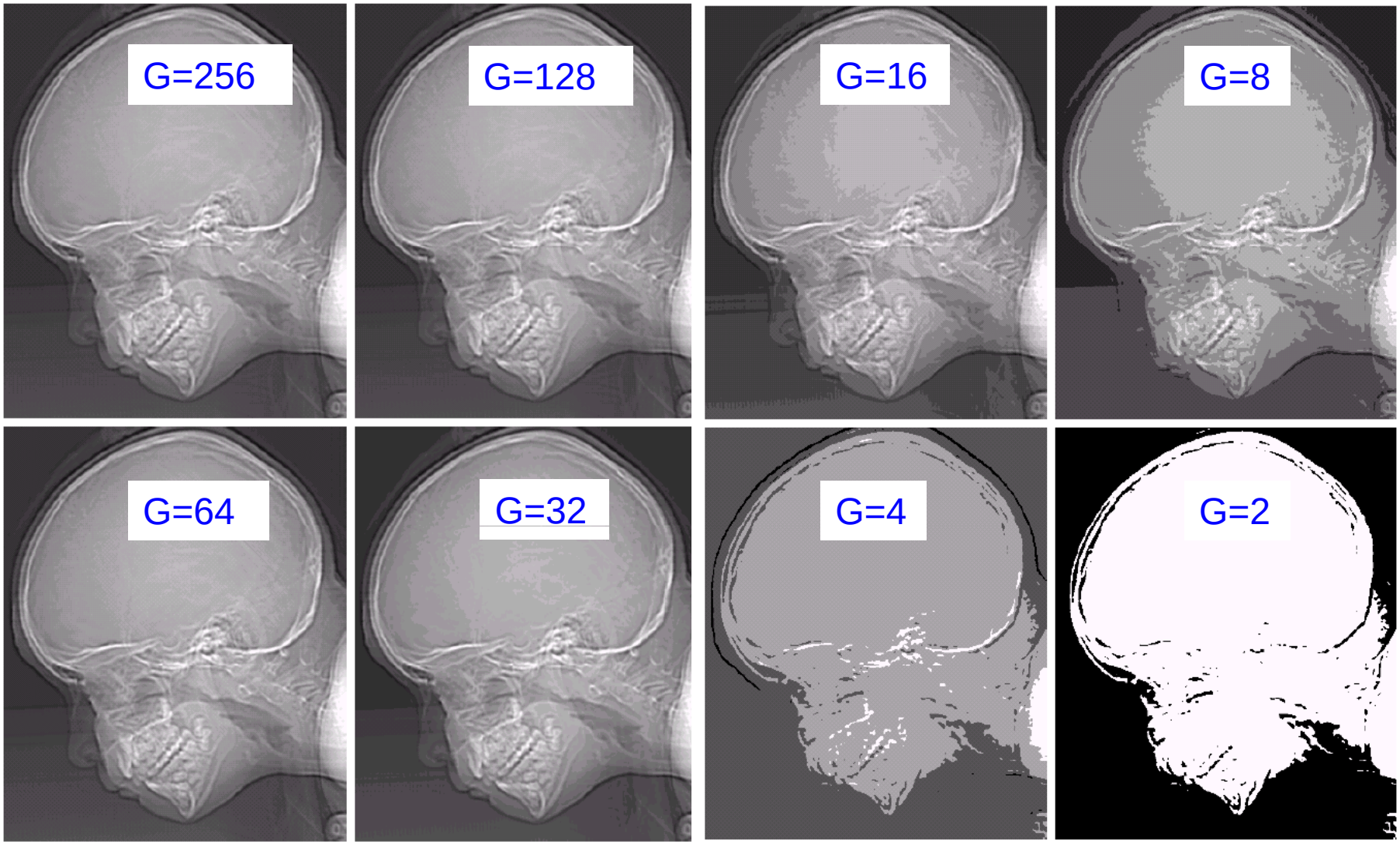
- The space, i.e. number of bits, required to store the image: N x M x k.
  - The more the values of N, M and $G=2^k$, the better approximation of a continuous image.
  - Storage and processing requirements increase as well.
  - N x M is called spatial resolution.
  - G is called gray-level resolution.

Effects of reducing spatial resolution

Effects of reducing spatial resolution



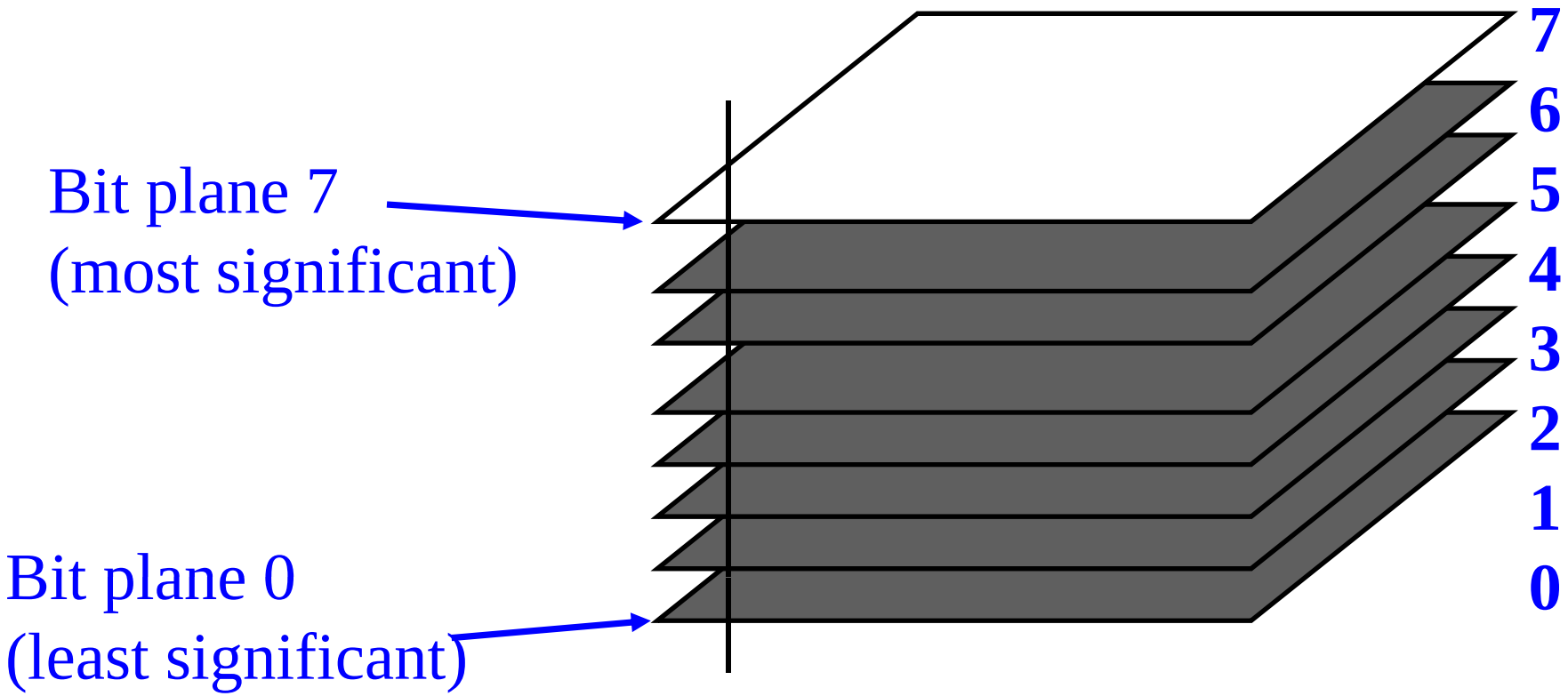
Effects of reducing gray level resolution



8-bit grey-level image

- Each pixel has a grey-value between 0 and 255.
- Thus each pixel can be represented by a single byte, i.e. 8 bits.
  - E.g., a dark pixel might have a value of 10, and a bright one might be 230.
- 8-bit image can be thought of as a set of 1-bit **bit-planes**, where each plane consists of a 1-bit representation of the image at higher and higher levels of “elevation”.

Bit-plane


Bit plane 7
(most significant)
Bit plane 0
(least significant)
7
6
5
4
3
2
1
0

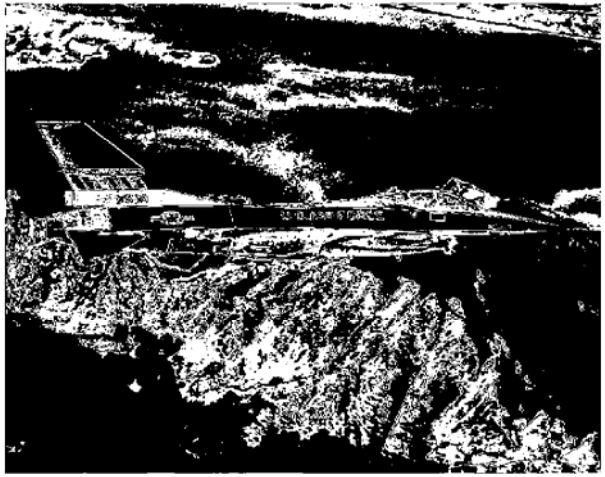
Bit-plane slicing

Original Image

Bit-plane slicing

Bit plane 7

Bit plane 6

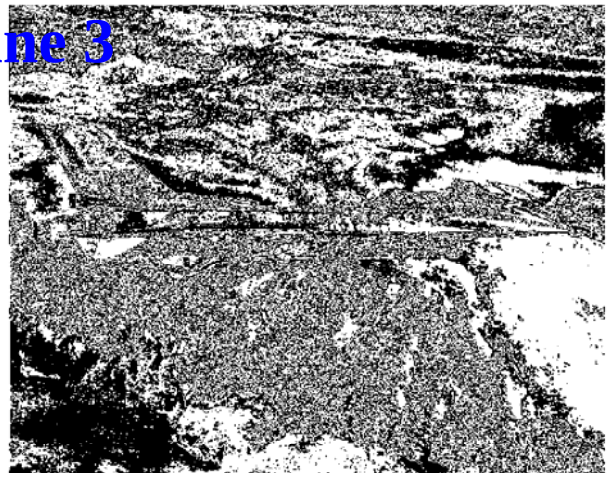


Bit plane 5

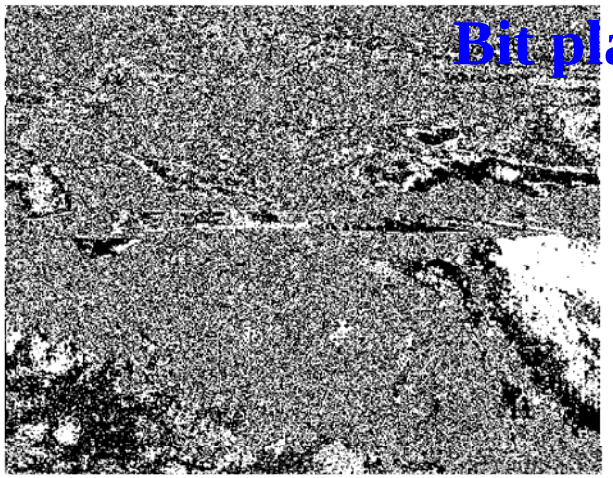
Bit plane 4

Bit-plane slicing

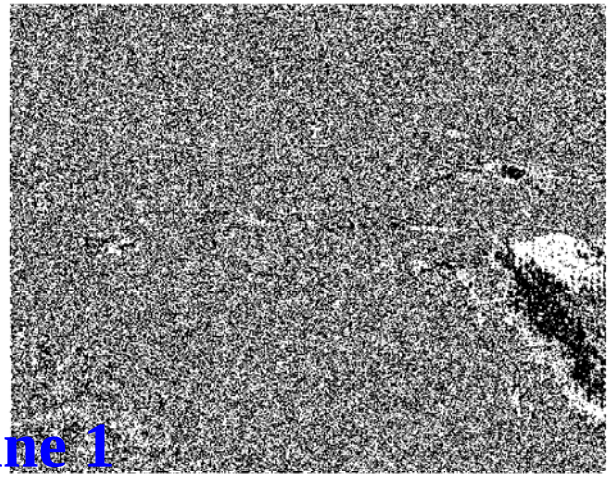
Bit plane 3



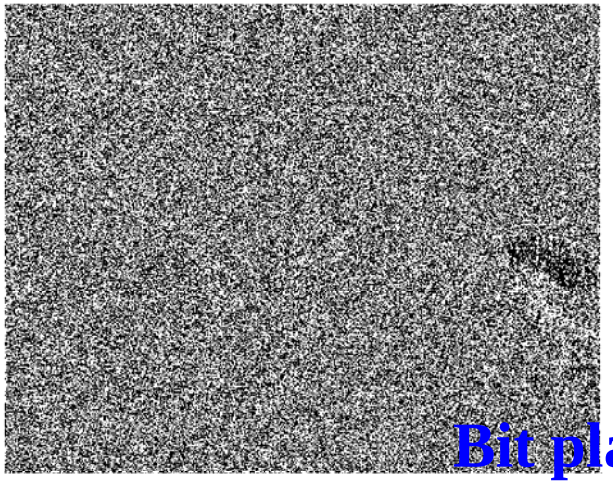
Bit plane 2



Bit plane 1



Bit plane 0



Bit-plane

- Higher order bit planes of an image carry a significant amount of visually relevant details.
- Lower order planes contribute more to fine (often imperceptible) details.

Exercise

- A 4x4 image is given as follow.

  What is the 7-th bit plane of this image?

17	**64**	**128**	**128**
15	**63**	**132**	**133**
11	**60**	**142**	**140**
11	**60**	**142**	**138**

1-bit image

- Each pixel is stored as a single bit (0 or 1), so also referred to as binary image.
- Such an image is also called black-white image because black is represented by 0 and white is represented by 1.

8-bit Lena

1-bit Lena

Grey to black&white: Matlab code

```
clear all;

I=imread('lena.tif', 'tif');
I=double(I);

T=100; %set the threshold

B=(I>100);
%B will be a binary image that has the same size of I.
%For those positions where I's value are greater than 100, the values in B
%will be 1; in other positions, the values in B are 0.

figure(1),clf;
imshow(I, [0 255]); % show the 8-bit image I

figure(2),clf;
imshow(B, [0 1]); % show the 1-bit image B
```

24-bit color image

- In a color 24-bit image, each pixel is represented by three bytes, usually representing RGB.
  - Supports 256×256×256 = 16,777,216 possible colors.
  - However such flexibility does result in a storage penalty: A 640×480 24-bit color image would require 921.6 kB of storage without any compression.
- Many 24-bit color images are actually stored as 32-bit images, with the extra byte of data for each pixel used to store an *alpha* value representing special effect information (e.g., transparency).

Example

24-bit full color image

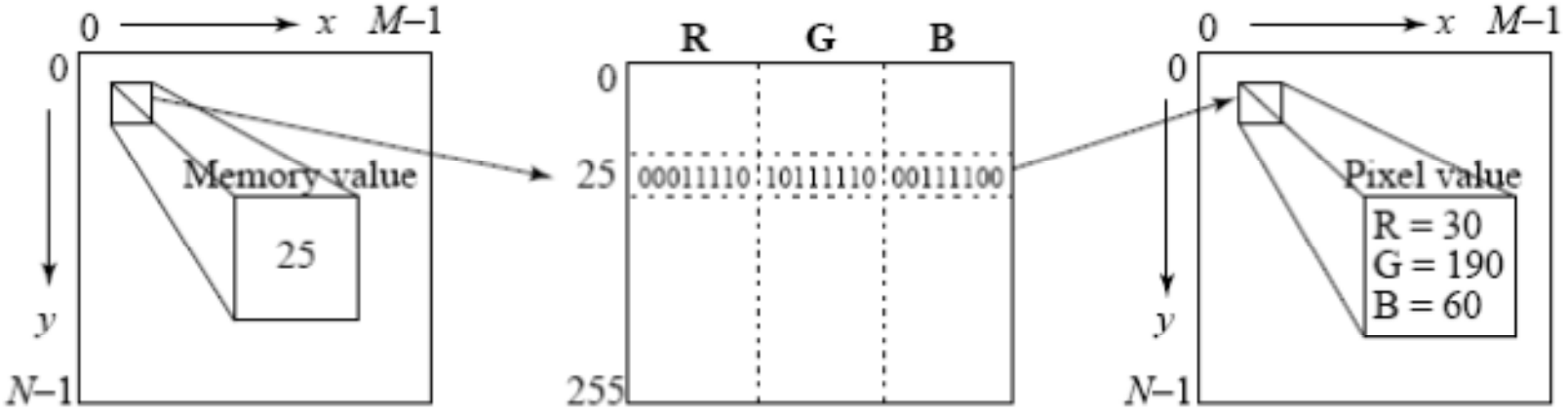
R channel

G channel

B channel

8-bit (256) safe color image

- Many systems can make use of 8 bits of color information (the so-called “256 colors”) in producing a screen image.
- The idea used in 8-bit color images is to store only the index, or code value, for each pixel. Then, e.g., if a pixel stores the value 25, the meaning is to go to row 25 in a color look-up table (LUT).

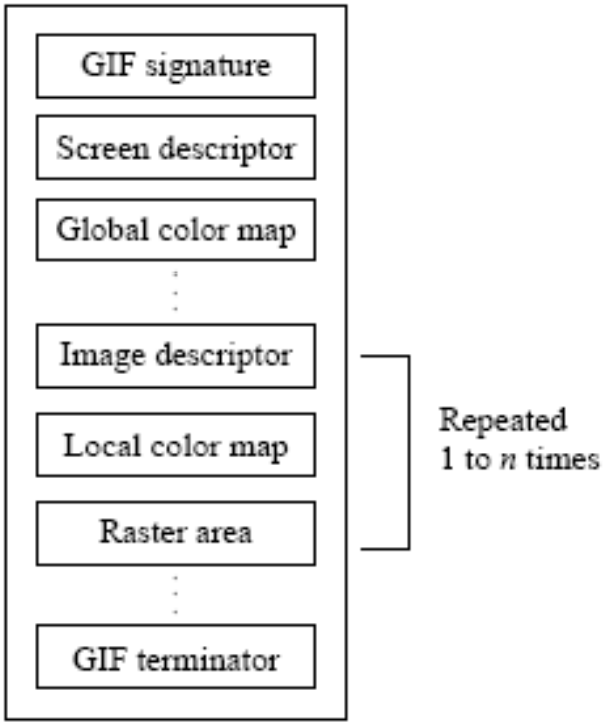


Example

- Note the great savings in space (of course in the price of degrading quality) for 8-bit images, over 24-bit ones: a 640×480 8-bit color image only requires 300 kB of storage, compared to 921.6 kB for a color image (again, without any compression applied).

Popular image file formats

- 8-bit GIF: Graphics Interchange Format. One of the most important format because of its historical connection to the WWW and HTML markup language as the first image type recognized by net browsers.
  - Producing acceptable color images, is best suited for images with few distinctive colors (e.g., graphics or drawing).
- GIF actually comes in two flavours:
  - GIF87a: The original specification.
  - GIF89a: The later version. Supports simple animation via a Graphics Control Extension block in the data, provides simple control over delay time, a transparency index, etc.



GIF 87

JPEG

- **JPEG** (Joint Photographic Experts Group): The most important current standard for image compression.
- The human vision system has some specific limitations and JPEG takes advantage of these to achieve high rates of compression.
- JPEG allows the user to set a desired level of quality, or compression ratio (input divided by output).

JPEG

- Quality factor Q=10%. This image is a mere 1.5% of the original size. In comparison, a JPEG image with Q=75% yields an image size 5.6% of the original.

TIFF

- **TIFF**: stands for Tagged Image File Format.
- The support for attachment of additional information (referred to as “tags”) provides a great deal of flexibility.
  - The most important tag is a format signifier: what type of compression etc. is in use in the stored image.
  - TIFF can store many different types of image: 1-bit, grayscale, 8-bit color, 24-bit RGB, etc.
  - TIFF was originally a lossless format but now a new JPEG tag allows one to opt for JPEG compression.
  - The TIFF format was developed by the Aldus Corporation in the 1980's and was later supported by Microsoft.

PNG

- **PNG**: Portable Network Graphics – meant to replace the GIF standard, and extends it in important ways.
- Special features of PNG files include:
  - Support for up to 48 bits of color information – a large increase.
  - Files may contain gamma-correction information for correct display of color images, as well as alpha-channel information for such uses as control of transparency.
  - The display progressively displays pixels in a 2-dimensional fashion by showing a few pixels at a time over seven passes through each 8×8 block of an image.

Graphics Animation Files

- A few dominant formats aimed at storing graphics animations (i.e., series of drawings or graphic illustrations) as opposed to video (i.e., series of images).
- Animations are considerably less demanding of resources than video files.
  - FLC is an animation or moving picture file format; it was originally created by Animation Pro. Another format, FLI, is similar to FLC.
  - GL produces somewhat better quality moving pictures. GL animations can also usually handle larger file sizes.
  - Many older formats: such as DL or Amiga IFF les, Apple Quicktime files, as well as animated GIF89 les.

PS

- Postscript (PS) is an important language for typesetting, and many high-end printers have a Postscript interpreter built into them.
- Postscript is a vector-based picture language, rather than pixel-based: page element definitions are essentially in terms of vectors.
  - PS includes text as well as vector/structured graphics.
  - Encapsulated PS (EPS) files add some additional information for inclusion of PS files in another document.
  - PS page description language itself does not provide compression; in fact, PS files are just stored as ASCII.

PDF

- Another text + figures language has begun to supersede or at least parallel Postscript: Adobe Systems Inc. includes LZW compression in its Portable Document Format (PDF) file format.
  - PDF files that do not include images have about the same compression ratio, 2:1 or 3:1, as do files compressed with other LZW-based compression tools.

References

- R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 3rd edition, Prentice Hall Inc., 2008.
- Ze-Nian Li, M. S. Drew, *Fundamentals of Multimedia*, Prentice Hall Inc., 2004. Chapter 3.