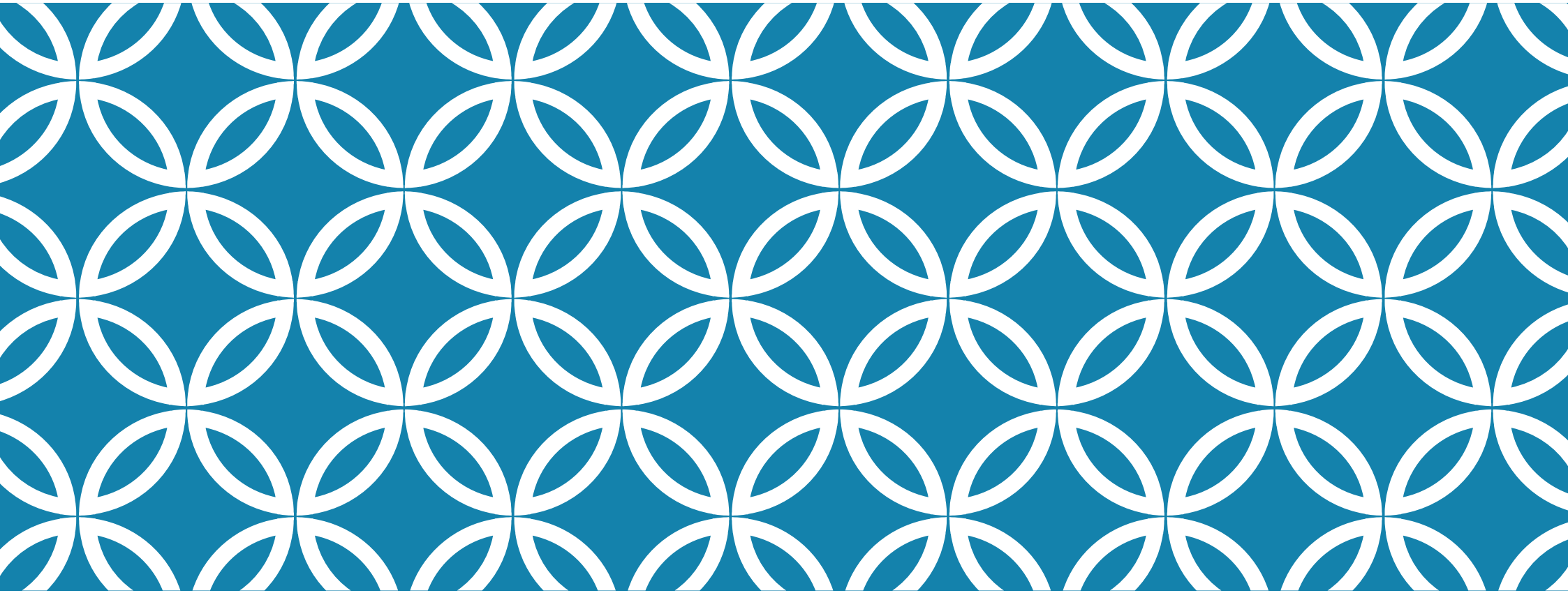


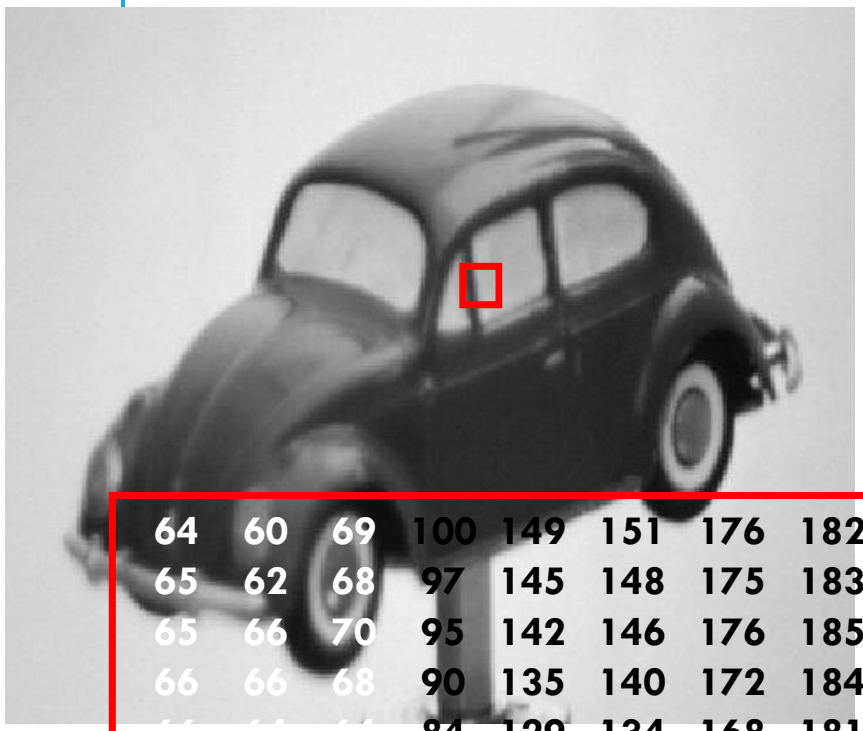
# IMAGE COMPRESSION

# IMAGE

## What is an Image ?

- The world around us is 3D while the image obtain through a camera is 2D,Hence an image can be defined as "A 2D representation of 3D world."
- A Digital Image is a representation of a two-dimensional image as a finite set of digital values, called **picture elements** or **pixels**.
- Each number represents the value of the function f(x,y) at any point. In this case the value 123 , 232,123 each represents an individual **pixel** value

# DIGITAL IMAGE STORE



| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 64 | 60 | 69 | 100 | 149 | 151 | 176 | 182 | 179 |
| 65 | 62 | 68 | 97 | 145 | 148 | 175 | 183 | 181 |
| 65 | 66 | 70 | 95 | 142 | 146 | 176 | 185 | 184 |
| 66 | 66 | 68 | 90 | 135 | 140 | 172 | 184 | 184 |
| | | | 84 | 129 | 134 | 168 | 181 | 182 |
| | | | 88 | 130 | 128 | 166 | 185 | 180 |
| | | | 85 | 127 | 125 | 163 | 183 | 178 |
| 62 | 62 | 58 | 81 | 122 | 120 | 160 | 181 | 176 |
| 63 | 64 | 58 | 78 | 118 | 117 | 159 | 180 | 176 |

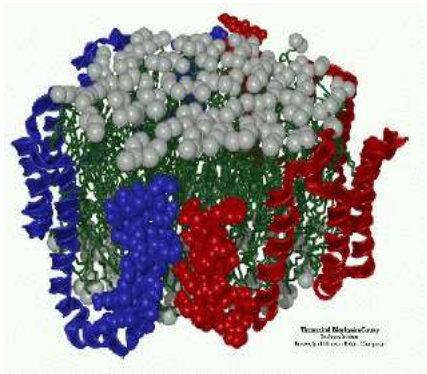
| y = | x = 58 | 59 | 60 | | | | | | | | | | | 71 | 72 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 210 | 209 | 204 | | | | | | | | | | | 7 | 58 |
| 42 | 206 | 196 | 203 | | | | | | | | | | | 2 | 51 |
| 43 | 201 | 207 | 192 | | | | | | | | | | | 0 | 50 |
| 44 | 216 | 206 | 211 | 193 | 202 | 207 | 208 | 57 | 69 | 60 | 55 | 77 | 49 | 62 | 61 |
| 45 | 221 | 206 | 211 | 194 | 196 | 197 | 220 | 56 | 63 | 60 | 55 | 46 | 97 | 58 | 106 |
| 46 | 209 | 214 | 224 | 199 | 194 | 193 | 204 | 173 | 64 | 60 | 59 | 51 | 62 | 56 | 48 |
| 47 | 204 | 212 | 213 | 208 | 191 | 190 | 191 | 214 | 60 | 62 | 66 | 76 | 51 | 49 | 55 |
| 48 | 214 | 215 | 215 | 207 | 208 | 180 | 172 | 188 | 69 | 72 | 55 | 49 | 56 | 52 | 56 |
| 49 | 209 | 205 | 214 | 205 | 204 | 196 | 187 | 196 | 86 | 62 | 66 | 87 | 57 | 60 | 48 |
| 50 | 208 | 209 | 205 | 203 | 202 | 186 | 174 | 185 | 149 | 71 | 63 | 55 | 55 | 45 | 56 |
| 51 | 207 | 210 | 211 | 199 | 217 | 194 | 183 | 177 | 209 | 90 | 62 | 64 | 52 | 93 | 52 |
| 52 | 208 | 205 | 209 | 209 | 197 | 194 | 183 | 187 | 187 | 239 | 58 | 68 | 61 | 51 | 56 |
| 53 | 204 | 206 | 203 | 209 | 195 | 203 | 188 | 185 | 183 | 221 | 75 | 61 | 58 | 60 | 60 |
| 54 | 200 | 203 | 199 | 236 | 188 | 197 | 183 | 190 | 183 | 196 | 122 | 63 | 58 | 64 | 66 |
| 55 | 205 | 210 | 202 | 203 | 199 | 197 | 196 | 181 | 173 | 186 | 105 | 62 | 57 | 64 | 63 |

# TYPES OF IMAGE

- original– thu nhận từ các thiết bị
  - camera, microscope, tomography, infrared, satellite, …
- synthesis–
  - Đồ họa máy tính (computer graphics), thực tại ảo (virtual reality)

Ảnh tự nhiên

ảnh nhân tạo

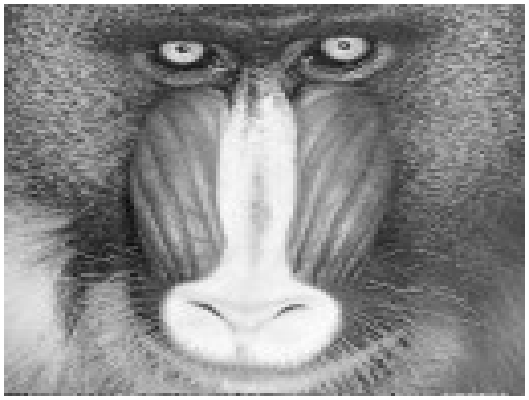


Ảnh nhân tạo

# TYPES OF DIGITAL IMAGE

## 1. Bit map Image /Monochrome/Binary

Each pixel consist of **single bit** either **0** or **1**,where 0 is black and 1 is white.



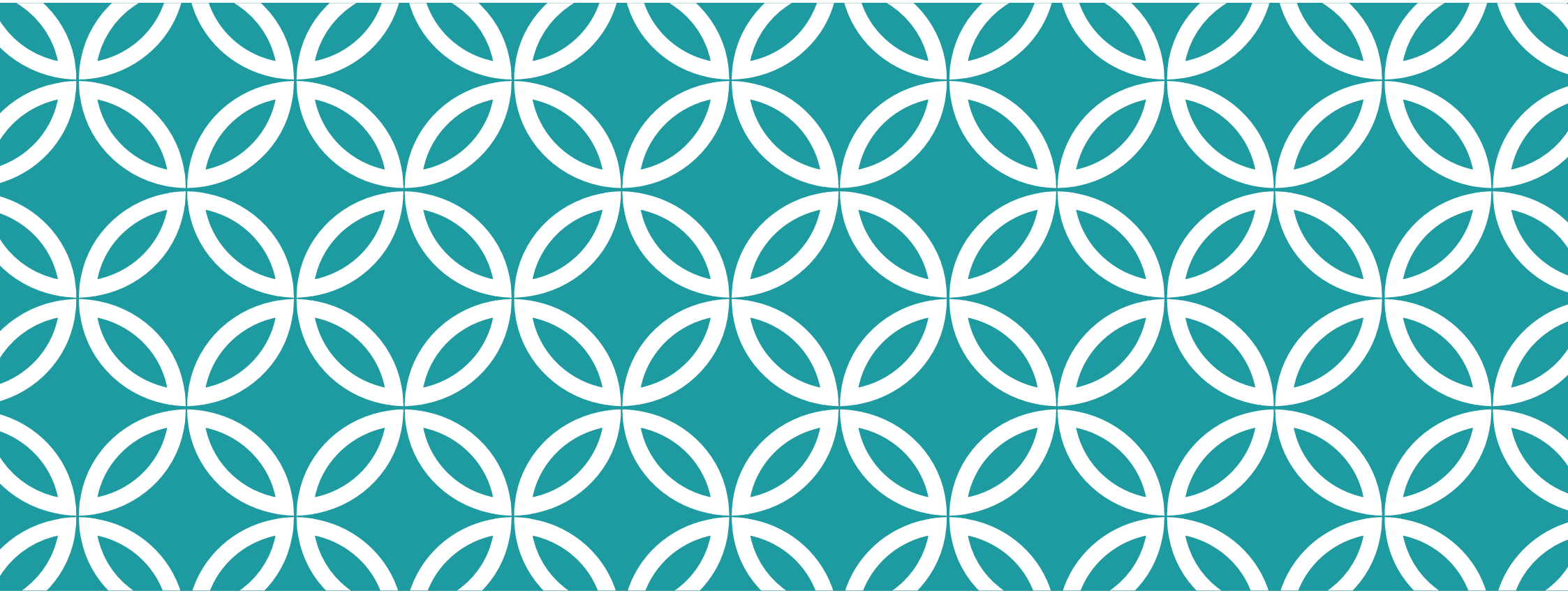
## 2. Gray-Scale Image

Each pixel consist of **eight bit** ,each bit range from **0** to **255**.

## 3.Colored Image

It consist of **3-primitive** colour **Red**, **Green** and **Blue** ,colored image consist of **24-bit** where 8-bit for red, 8-bit for green and 8-bit for blue.

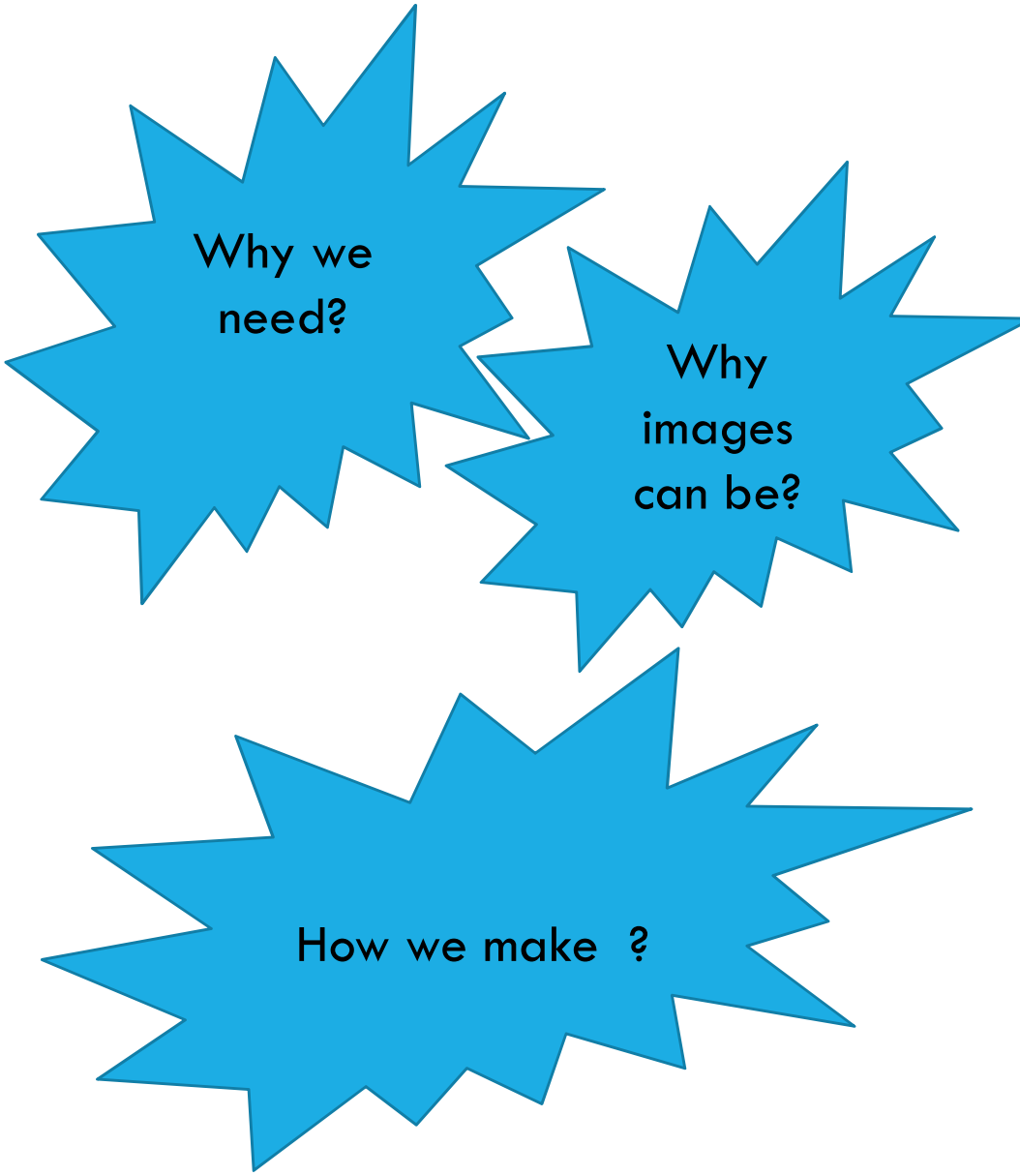
*Source : Tal Hassner. Computer Vision. Weizmann Institute of Science (Israel).*



# IMAGE COMPRESSION

# IMAGE COMPRESSION

Image compression is the method of data compression on digital images.



# WHY WE NEED?

The main objective in the image compression is:

- Store data in an efficient form
- Transmit data in an efficient form

Techniques for reducing the storage required to save an image or the bandwidth required to transmit it.

Image compression address the problem of **reducing the amount of data** required to represent a digital image with **no significant loss** of information.

Image compression can be lossy or lossless.

# WHY WE CAN?

- **Image** = **Information** + **Redundant Data**
- Image compression techniques fall into Two categories:

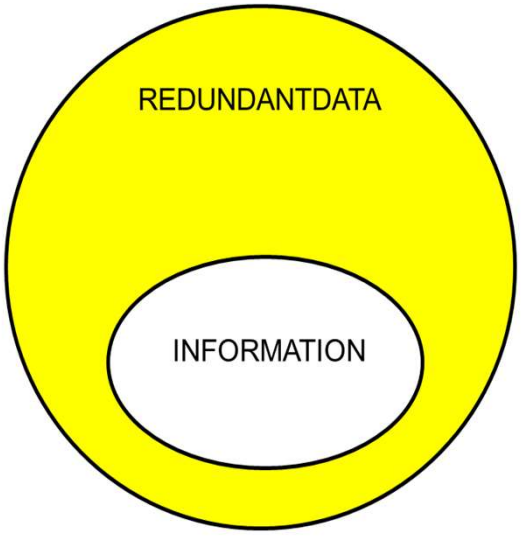
**Lossless :** Information preserving ,Low compression ratios .

**Lossy :** Not information preserving ,High compression ratios .

# FUNDAMENTALS

- Data compression refers to the process of reducing the amount of data required to represent a given quantity of information.
- Data and Information are not the same thing, **Data** is the means by which **information** is conveyed.
- Data compression aims to **reduce** the amount of data required to represent a given quantity of information while **preserving** as much information as possible.

# FUNDAMENTALS



DATA = INFORMATION + REDUNDANT DATA

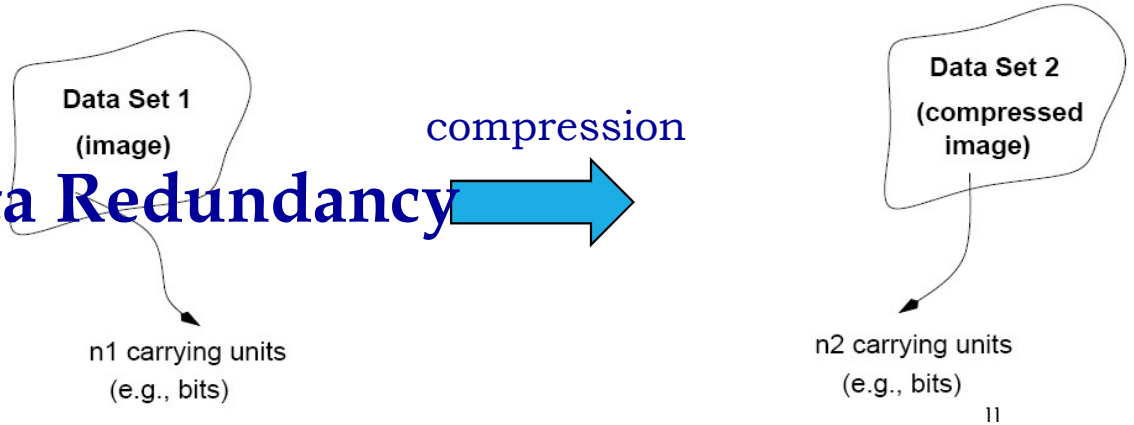
- **Data Redundancy**

It contains data (or words) that either provide no relevant information or simply restate that which is already known.

- The Relative **data redundancy $R_D$** of the first data set ,is defined by :

$$R_D = 1 - \frac{1}{C_R}$$

Where, **$R_D$** is **Relative Data Redundancy** ,**$C_R$** is **Compression ratio**.



# CODING REDUNDANCY

- **Code:** A list of symbols (letters, numbers, bits etc) .
- **Code word:** A sequence of symbols used to represent a piece of information or an event (e.g., gray levels).
- **Code word length:** Number of symbols in each code word

Example: (binary code, symbols: 0,1, length: 3)

| | |
|---|---|
| 0: 000 | 4: 100 |
| 1: 001 | 5: 101 |
| 2: 010 | 6: 110 |
| 3: 011 | 7: 111 |

# INTERPIXEL REDUNDANCY

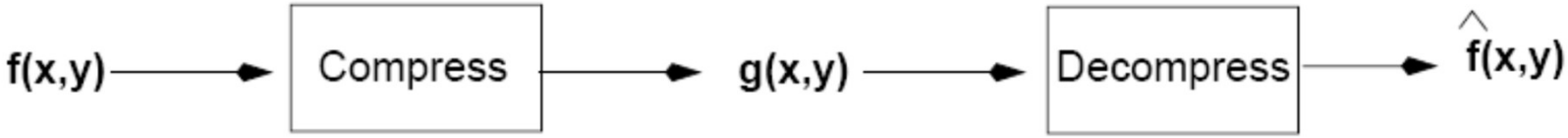
- It is also called **Spatial & Temporal redundancy.**
- Because the pixels of most 2D intensity arrays are correlated spatially(i.e. **Each pixel is similar to or dependent on neighbor pixel**), information is replicated unnecessarily .
- This type of redundancy is related with the Interpixel correlations within an image.
- In video sequence, temporally correlated pixels also duplicate information. The codes used to represent the gray levels of each image have nothing to do with correlation between pixel.

# PSYCHOVISUAL REDUNDANCY

- Certain information has relatively less importance for the quality of **image perception.** This information is said to be **psychovisually redundant.**
- Unlike **coding** and **interpixel redundancies**, the Psychovisual redundancy is related with the **real/quantifiable** visual information. Its elimination results a loss of quantitative information. However psychovisually the loss is negligible.
- Removing this type of redundancy is **a lossy** process and the lost information cannot be **recovered.**
- The method used to remove this type of redundancy is called **quantization** which means the mapping of a broad range of input values to a limited number of output values.

# FIDELITY CRITERIA

- When lossy compression techniques are employed, the decompressed image will not be identical to the original image. In such cases , we can define **fidelity criteria** that measure the difference between this two images.




**How close is** $f(x,y)$ **to** $\hat{f}(x,y)$ **?**

$$\hat{f}(x,y) = f(x,y) + e(x,y)$$

- Two general classes of criteria are used :

  **(1) Objective fidelity criteria**

  **(2) Subjective fidelity criteria**

# VARIABLE-LENGTH CODING

- The coding redundancy can be minimized by using a variable-length coding method where the shortest codes are assigned to most probable gray levels.
- The most popular variable-length coding method is the **Huffman Coding**. **Huffman Coding:** The Huffman coding involves the following 2 steps.

1) Create a series of source reductions by ordering the probabilities of the symbols and combining the lowest probability symbols into a single symbol and replace in the next source reduction.

2) each Code reduced source starting with the smallest source and working back to the original source.

# IMAGE COMPRESSION MODEL

- The image compression system is composed of 2 distinct functional component: an **encoder** & a **decoder**.
- Encoder performs **Compression** while Decoder performs **Decompression**. Encoder is used to remove the redundancies through a **series of 3 independent operations**.
- Both operations can be performed in Software, as in case of Web browsers & many commercial image editing programs. Or in a combination of hardware & firmware, as in DVD Players.
- A **codec** is a device which performs coding & decoding.

# VARIABLE-LENGTH CODING

**1)Huffman source reductions:**

ai's corresponds to the available gray levels in a given image.

| Original source | | Source reduction | | | |
|---|---|---|---|---|---|
| Symbol | Probability | 1 | 2 | 3 | 4 |
| $a_2$ | 0.4 | 0.4 | 0.4 | 0.4 | 0.6 |
| $a_6$ | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 |
| $a_1$ | 0.1 | 0.1 | 0.2 | 0.3 | |
| $a_4$ | 0.1 | 0.1 | 0.1 | | |
| $a_3$ | 0.06 | 0.1 | | | |
| $a_5$ | 0.04 | | | | |

# VARIABLE-LENGTH CODING

## 2) Huffman code assignments:

The first code assignment is done for **a2** with the **highest probability** and the last assignments are done for **a3** and **a5** with the **lowest probabilities.**

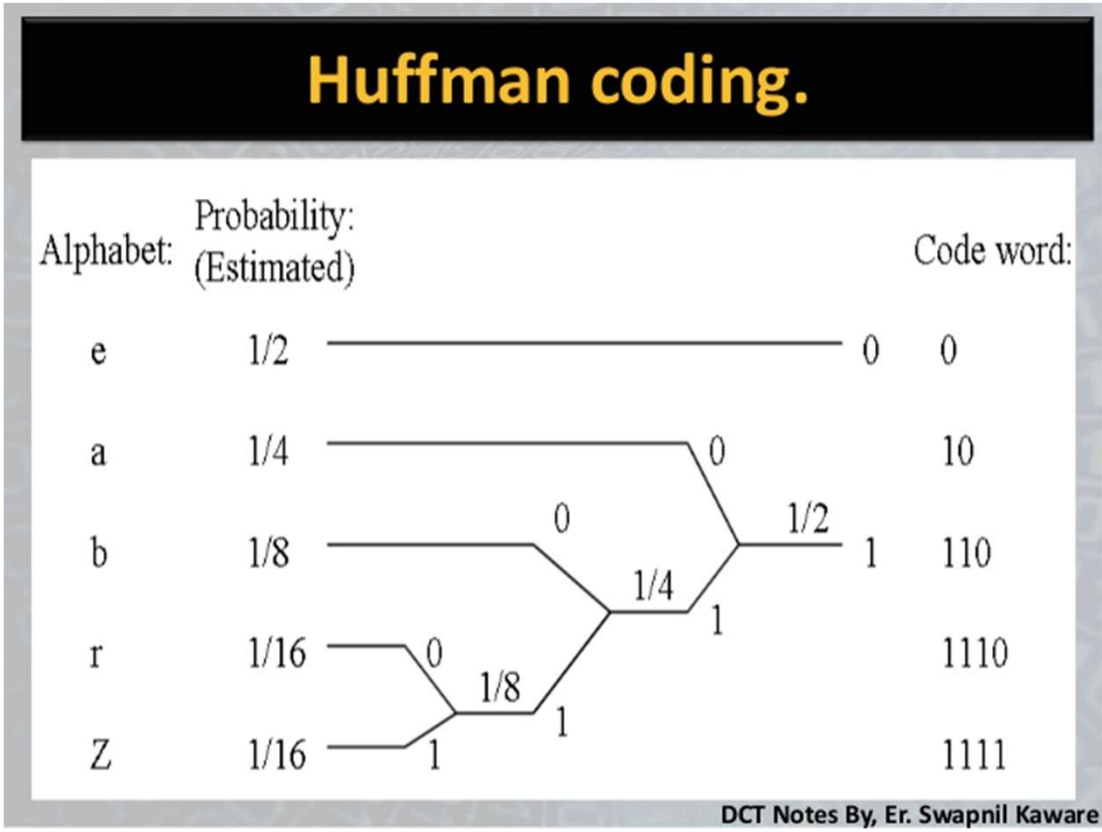
| Original source | | | Source reduction | | | |
|---|---|---|---|---|---|---|
| Sym. | Prob. | Code | 1 | 2 | 3 | 4 |
| $a_2$ | 0.4 | 1 | 0.4 1 | 0.4 1 | 0.4 1 | 0.6 0 |
| $a_6$ | 0.3 | 00 | 0.3 00 | 0.3 00 | 0.3 00 | 0.4 1 |
| $a_1$ | 0.1 | 011 | 0.1 011 | 0.2 010 | 0.3 01 | |
| $a_4$ | 0.1 | 0100 | 0.1 0100 | 0.1 011 | | |
| $a_3$ | 0.06 | 01010 | 0.1 0101 | | | |
| $a_5$ | 0.04 | 01011 | | | | |

# HUFFMAN CODING

Arrange symbols: $p(s_2) > p(s_5) > \ldots > p(s_3)$

$l_i$ = length in bits of the *i'th* symbol $s_i$

Key idea: use fewer bits to code the most likely symbols: $l_2 < l_5 < \ldots < l_3$



# HUFFMAN CODING

Advantages

✓ maximum compression ratio assuming correct probabilities of occurrence

✓easy to implement and fast ☐

Disadvantages

need two passes for both encoder and decoder ☐

- one to create the frequency distribution ☐
- one to encode/decode the data

can avoid this by sending tree (takes time) or by having unchanging frequencies

# VARIABLE-LENGTH CODING

- The shortest codeword (1) is given for the symbol/pixel with the highest probability (a2). The longest codeword (01011) is given for the symbol/pixel with the lowest probability (a5).
- The **average length of the code** is given by:

$$L_{avg} = (0.4)(1) + (0.3)(2) + (0.1)(3) + (0.1)(4) + (0.06)(5) + (0.04)(5)$$
$$= 2.2 \; bits \; / \; symbol$$

# VARIABLE-LENGTH CODING

It is **uniquely decodable. Because** any string of code symbols can be decoded by examining individual symbols of string from left to right.

- Ex. 01010 011 1 1 00
- First valid code: 01010 – a3, 011 – a1,
- Thus, completely decoding the message, we get, a3a1a2a2a6
- Slower than Huffman coding but typically **achieves better compression.**

# LEMPEL–ZIV–WELCH (LZW)

- **Lempel–Ziv–Welch (LZW)** is a universal lossless data compression algorithm created by **Abraham Lempel, Jacob Ziv, and Terry Welch.**
- The key to LZW is building a dictionary of sequences of symbols (strings) as the data is read and compressed.
- Whenever a string is repeated, it is replaced with a single code word in the output.
- At **decompression time**, the same dictionary is created and used to replace code words with the corresponding strings.

# LEMPEL–ZIV–WELCH (LZW)

- A **codebook** (or **dictionary)** needs to be constructed. **LZW** compression has been integrated into a several images file formats, such as **GIF** and TIFF and **PDF**.
- Initially, the **first 256** entries of the dictionary are assigned to the **gray levels 0,1,2,..,255 (i.e., assuming 8 bits/pixel)**

Consider a 4x4, 8 bit image

39 39 126 126
39 39 126 126
39 39 126 126
39 39 126 126

**Initial Dictionary**

| Dictionary Location | Entry |
|---|---|
| 0 | 0 |
| 1 | 1 |
| . | . |
| 255 | 255 |
| 256 | - |
| 511 | - |

# LEMPEL–ZIV–WELCH (LZW)

As the encoder examines image pixels, gray level sequences (i.e., blocks) that are not in the dictionary are assigned to a new entry.

| Dictionary Location | Entry |
|---|---|
| 0 | 0 |
| 1 | 1 |
| . | . |
| 255 | 255 |
| 256 | 39-39 |
| 511 | - |

**39 39 126 126**
**39 39 126 126**
**39 39 126 126**
**39 39 126 126**

- Is **39** in the dictionary……..**Yes**
- What about **39-39**…….No
  * Add 39-39 at location 256

# RUN LENGTH CODING

Run-length encoding (RLE) is a very simple form of lossless data compression in which runs of data

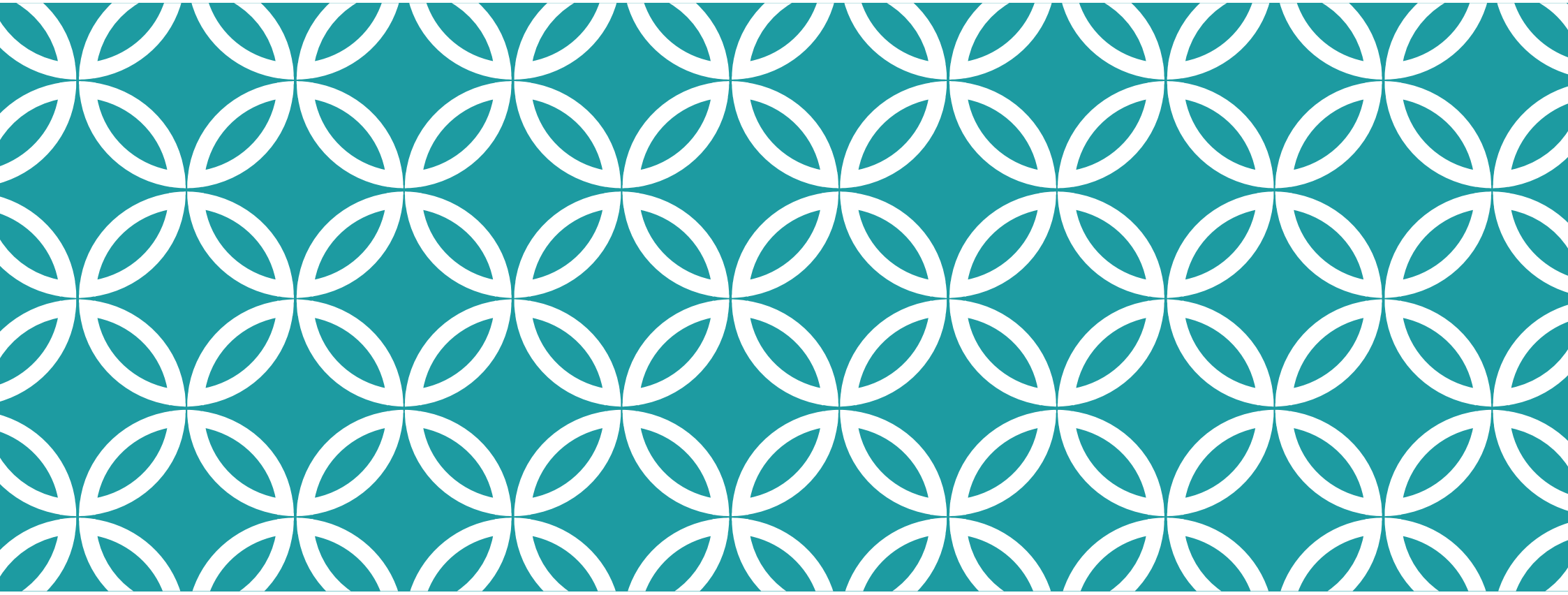
Input: 7,7,7,7,7,13,90,9,9,9,2,1,1,0,5,…= 15 Byte

RLE: 5,7,13,90,3,9,2,2,1,0,5,…= 11 Byte

How to distinguish between values and counts?

One value of a byte to indicate a count, e.g. 0 or 255, e.g. 255: 255,5,7,13,90,255,3,9,2,255,2,1,0,5,…= 14 Byte

One bit to indicate count [1] and value [0] for 8 values => [10001001],5,7,13,90,3,9,2,2,[000…]1,0,5.. ~ 12,5 Byte



# JPEG STANDARD

# JPEG STANDARD

"Joint Photographic Expert Group". Voted as international standard in 1992.

Works with color and grayscale images, e.g., satellite, medical, ...

Lossy and lossless

**Joint Photographic Experts Group**

A photo of a cat with the compression rate decreasing, and hence quality increasing, from left to right.

| | |
|---|---|
| **Filename extension** | `.jpg`, `.jpeg`, `.jpe`, `.jif`, `.jfif`, `.jfi` |
| **Internet media type** | `image/jpeg` |
| **Type code** | `JPEG` |
| **Uniform Type Identifier (UTI)** | public.jpeg |
| **Magic number** | `ff d8 ff` |
| **Developed by** | Joint Photographic Experts Group |
| **Initial release** | September 18, 1992; 24 years ago |
| **Type of format** | lossy image format |
| **Standard** | ISO/IEC 10918, ITU-T T.81, ITU-T T.83, ITU-T T.84, ITU-T |

# JPEG STANDARD

1987: ITU + ISO => international standard for still image compression, due to grows in the PC market: JPEG = Joint Photographic Expert Group

Goal: non-binary images keeping a good to excellent image quality

First standard in 1992

JPEG is NOT an algorithm but rather a framework with several algorithms and user-settings

# III.4 NÉN ẢNH : JPEG

The JPEG compression algorithm is at its best on photographs and paintings of realistic scenes with smooth variations of tone and color.

JPEG uses a lossy form of compression based on the discrete cosine transform (DCT)

First generation JPEG uses DCT + Run length Huffman entropy coding.

Second generation JPEG (JPEG2000) uses wavelet transform + Bit plane coding + Arithmetic entropy coding.

# III.4 NÉN ẢNH: JPEG

Các thông tin tần số cao có thể bị loại bỏ mà không làm mất mát thông tin quan sát vì mắt người không cảm nhận được những hiệu ứng do các thành phần tần số cao mang lại một cách chính xác

Ảnh được chuyển sang miền tần số sử dụng phép biến đổi Cosin rời rạc - Discrete Cosine Transform (DCT)

Phép biến đổi DCT thường được áp dụng cho các khối pixel kích thước $8 \times 8$.

Việc áp dụng DCT không làm giảm kích thước của dữ liệu, vì số các hệ số của DCT cũng bằng tổng số pixel của khối (64).

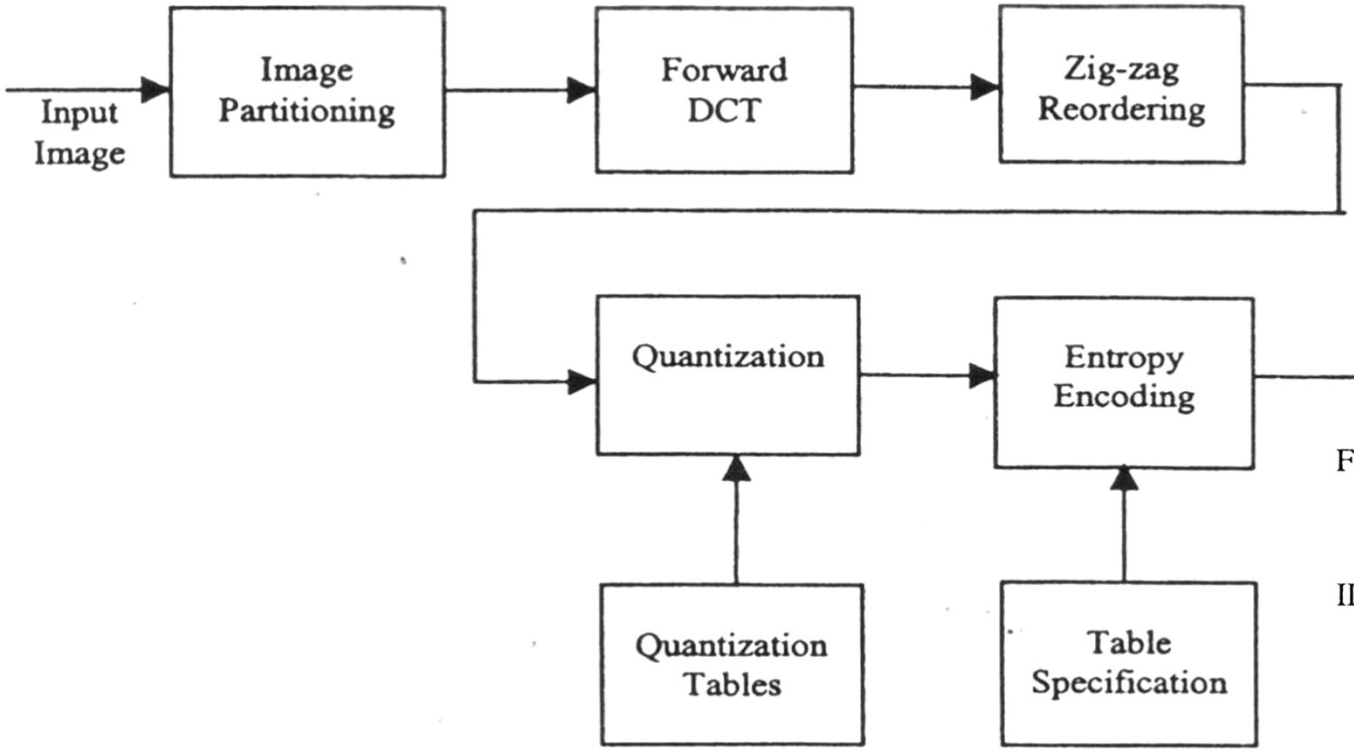
Tuy nhiên, các hệ số của DCT được lượng tử hóa, vì thế số bit cần thiết để biểu diễn các hệ số DCT sẽ giảm đi. Việc lượng tử hóa sẽ làm biến mất một số thông tin.

# JPEG COMPRESSION

DCT is similar to DFT, but can provide a better approximation with fewer coefficients

The coefficients of DCT are real valued instead of complex valued in DFT.

# JPEG




FDCT: $$S_{uv} = \frac{1}{4} C_u C_v \sum_{i=0}^{7} \sum_{j=0}^{7} s_{ij} \cos\frac{(2i+1)u\pi}{16} \cos\frac{(2j+1)v\pi}{16}$$

IDCT: $$s_{ij} = \frac{1}{4} \sum_{u=0}^{7} \sum_{v=0}^{7} C_u C_v S_{uv} \cos\frac{(2i+1)u\pi}{16} \cos\frac{(2j+1)v\pi}{16}$$

$$C_u C_v = \begin{cases} \frac{1}{\sqrt{2}} & \text{for } u, v = 0 \\ 1 & \text{otherwise} \end{cases}$$

**FIGURE 7.3** Block diagram of a sequential DCT-based encoding process.

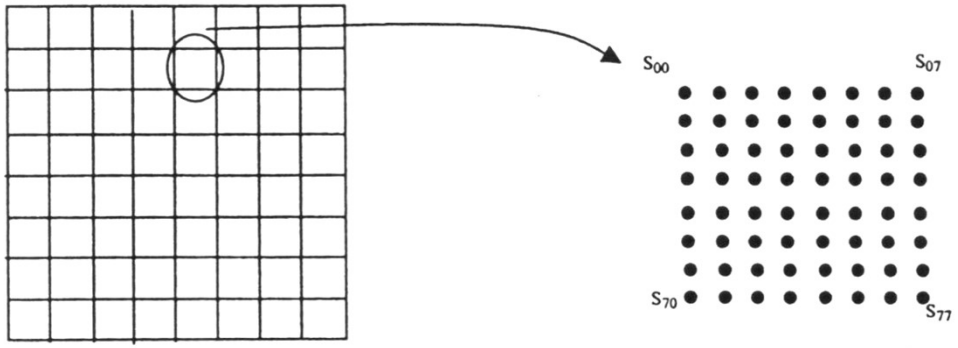



**FIGURE 7.4** Partitioning to $8 \times 8$ blocks.

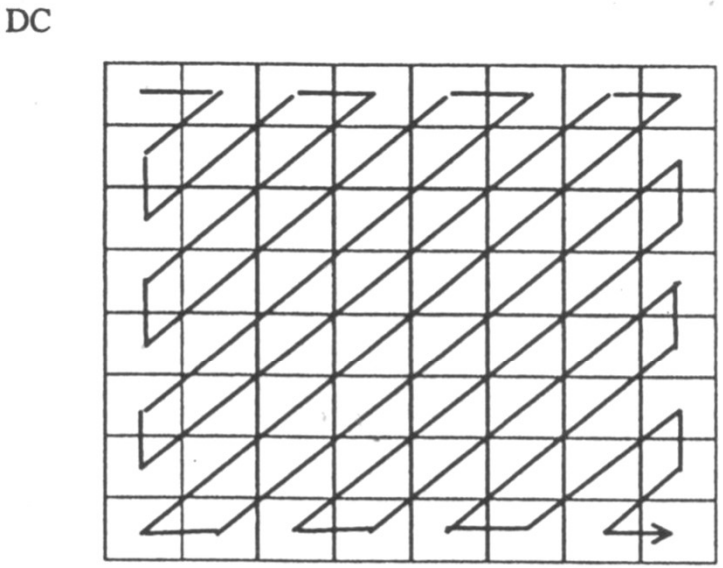
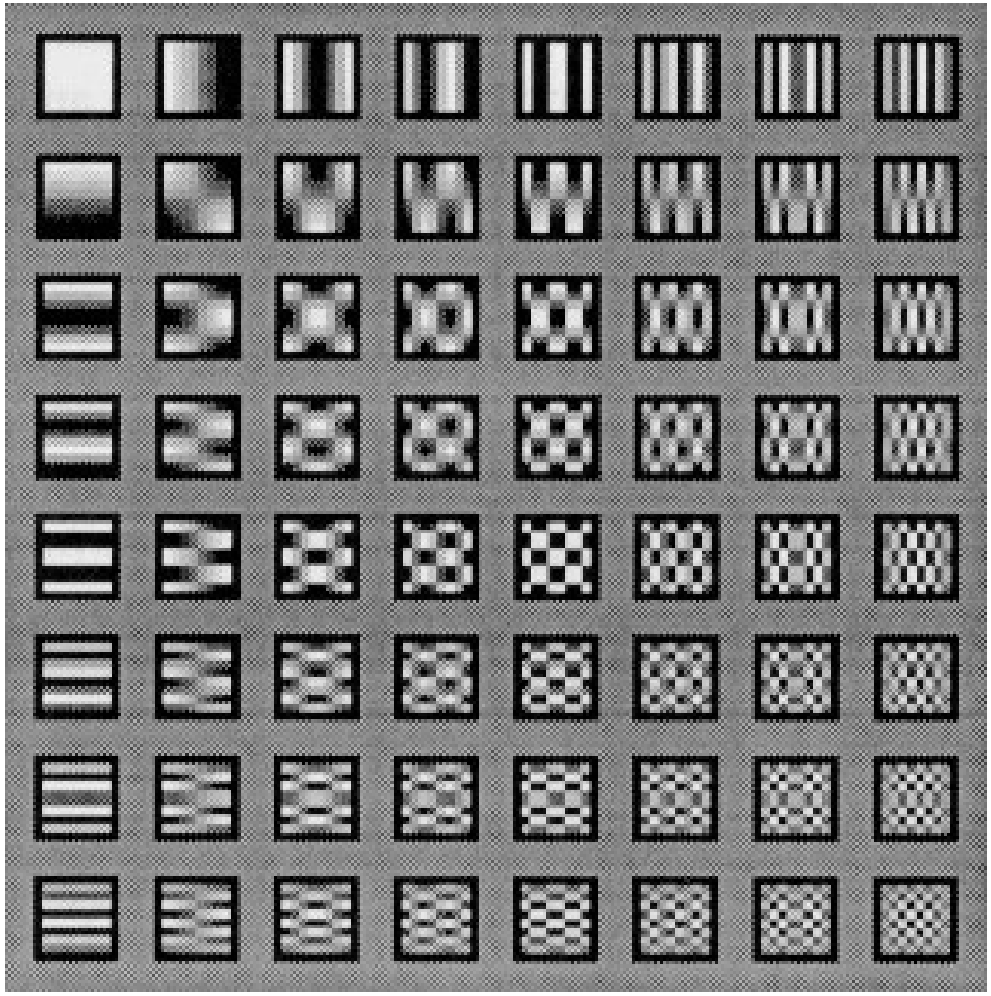



**FIGURE 7.5** Zigzag scanning order of DCT coefficients.

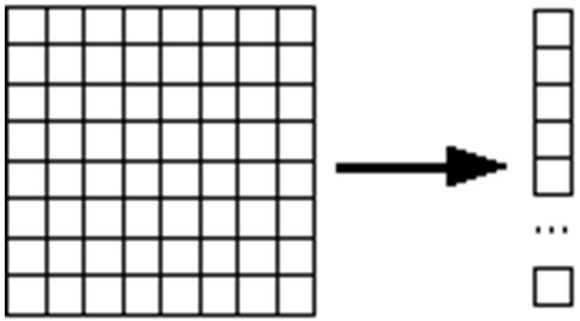
# THE 64 (8 X 8) DCT BASIS FUNCTIONS

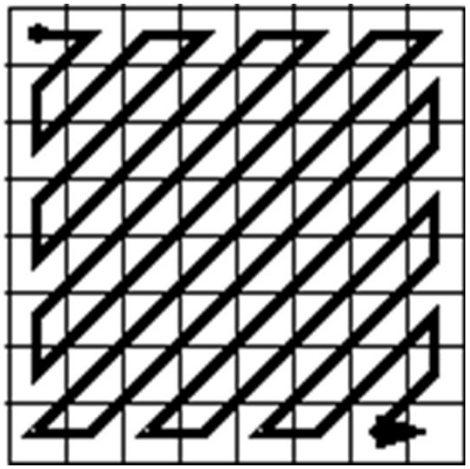
- Each 8x8 block can be looked at as a weighted sum of these basis functions.
- The process of 2D DCT is also the process of finding those weights.

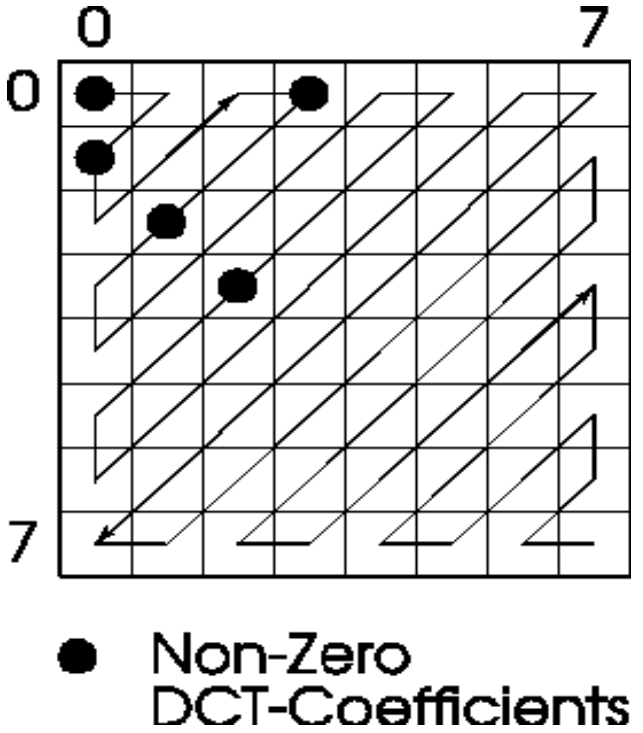


# ZIG-ZAG SCAN DCT BLOCKS

- Why? -- To group low frequency coefficients in top of vector.
- Maps 8 x 8 to a 1 x 64 vector.







This mathematical operation converts each frame/field of the video source from the spatial (2D) domain into the frequency domain

A perceptual model based loosely on the human psychovisual system discards high-frequency information

In the transform domain, the process of reducing information is called quantization.

the transform-domain is a convenient representation of the image because the high-frequency coefficients, which contribute less to the overall picture than other coefficients, are characteristically small-values with high compressibility.

The quantized coefficients are then sequenced and losslessly packed into the output bitstream.


J.P.G.


J.P.G.


J.P.G.


J.P.G.

# ẢNH GỐC & JPEG 1:27 & JPEG2000

# JPEG

## Original image

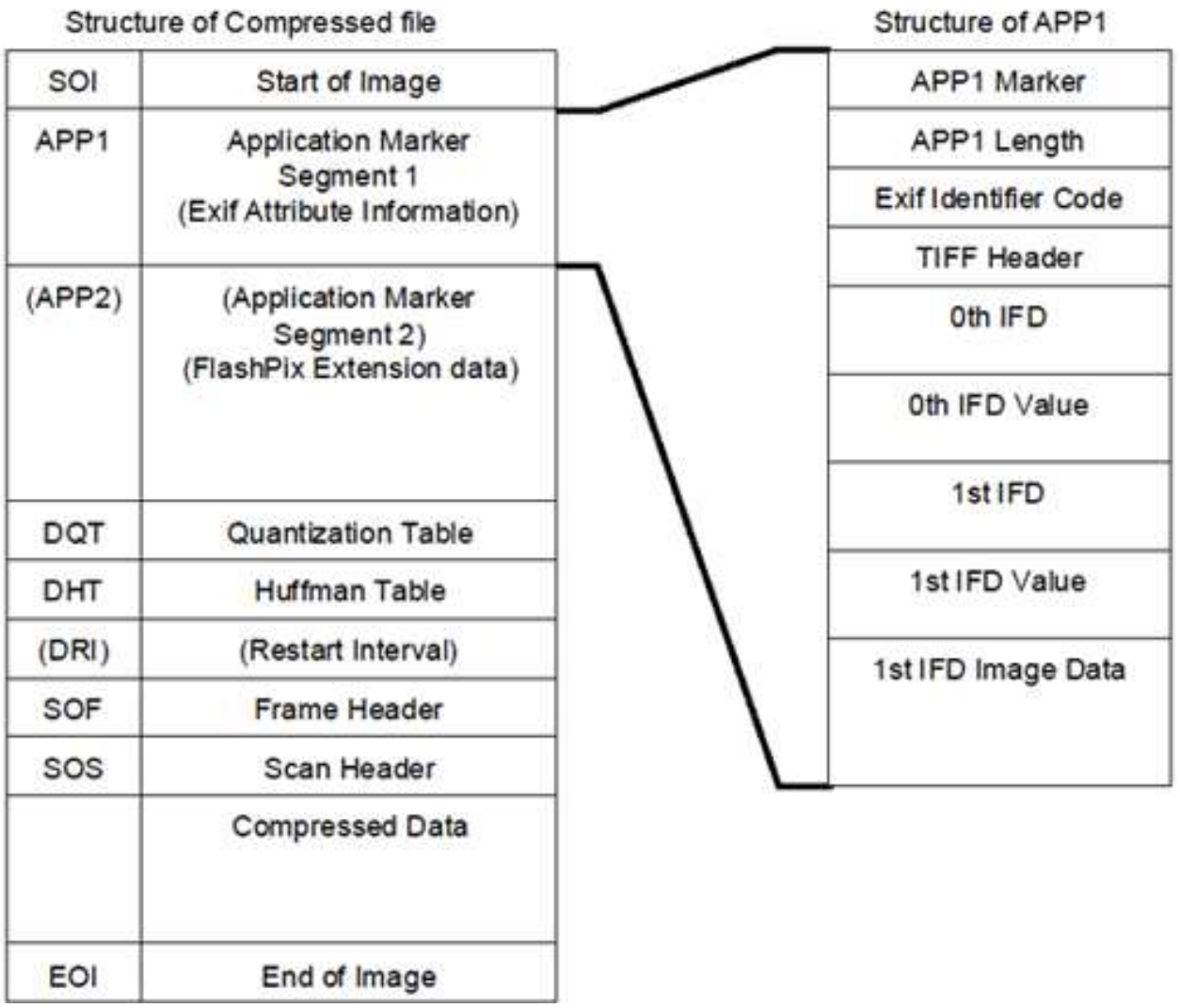
512 x 512 x 8 bits

= 2,097,152 bits

## JPEG

27:1 reduction

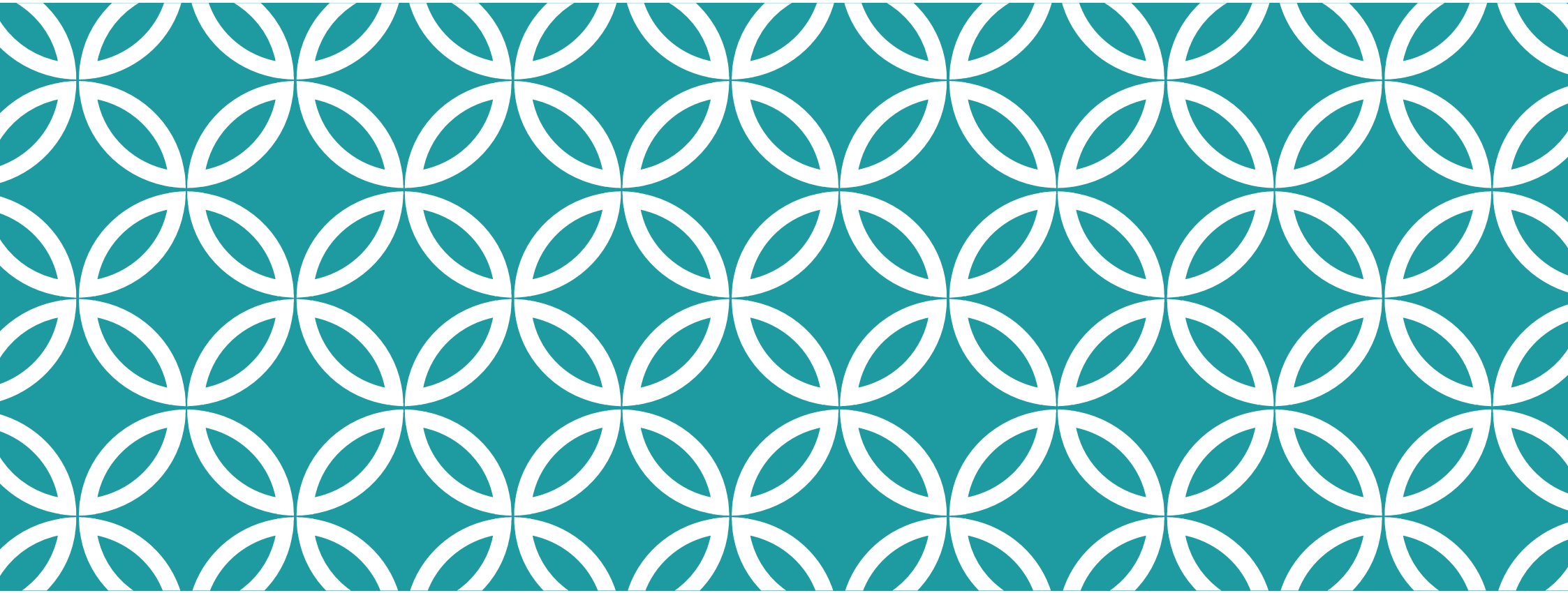
=77,673 bits



# EXERCISE

- Why is it possible to compress images?
- Explain the JPEG framework
- What is the compression factor of this luminance DCT-block?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 130 | 5 | 4 | -34 | 11 | -17 | 14 | 10 |
| 2 | 47 | 6 | 1 | -8 | 14 | 21 | 22 |
| -19 | 1 | -2 | -3 | 6 | 3 | -1 | -21 |
| -3 | 5 | -1 | 5 | -1 | -2 | 17 | 11 |
| 7 | -9 | 2 | 10 | 9 | 1 | -4 | 9 |
| 2 | 4 | -6 | -11 | 12 | -7 | 40 | -17 |
| -1 | -12 | -3 | 1 | 9 | 14 | 57 | 34 |
| 22 | 5 | 4 | -2 | 33 | -21 | 14 | -27 |



# IMAGE FILE EXTETION

# IMAGE FILE EXTENTION

GIF

PNG

JPEG

TiFF

BMP


Original file .tiff

.bmp .jpg

.gif .png

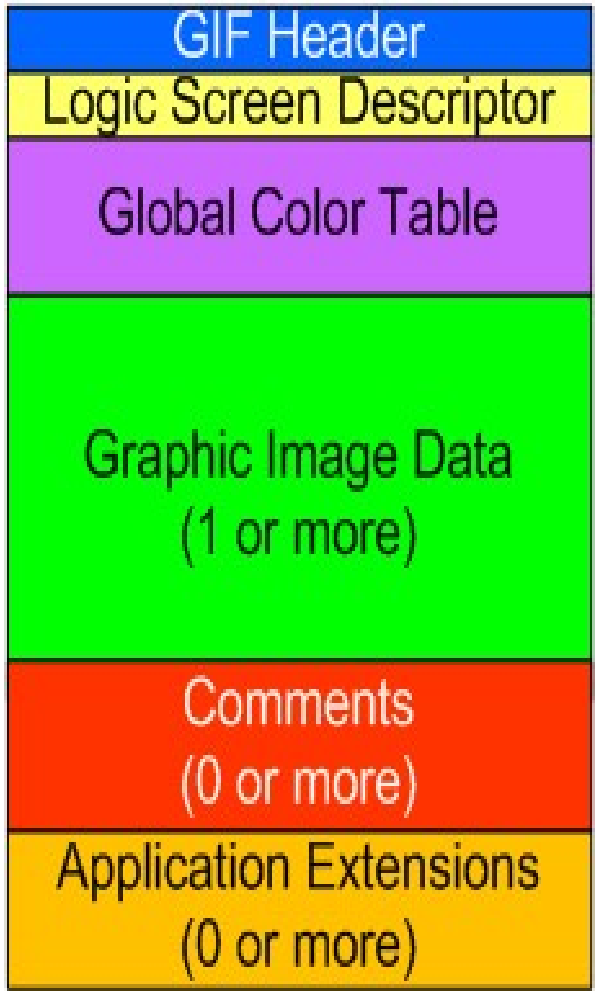
# GRAPHICS INTERCHANGE FORMAT - GIF

is a bitmap image format that was developed by provider CompuServe on 1987 and widespread usage on the World Wide Web

The format supports up to 8 bits per pixel for each image, palette of up to 256 different colors, It also supports animations

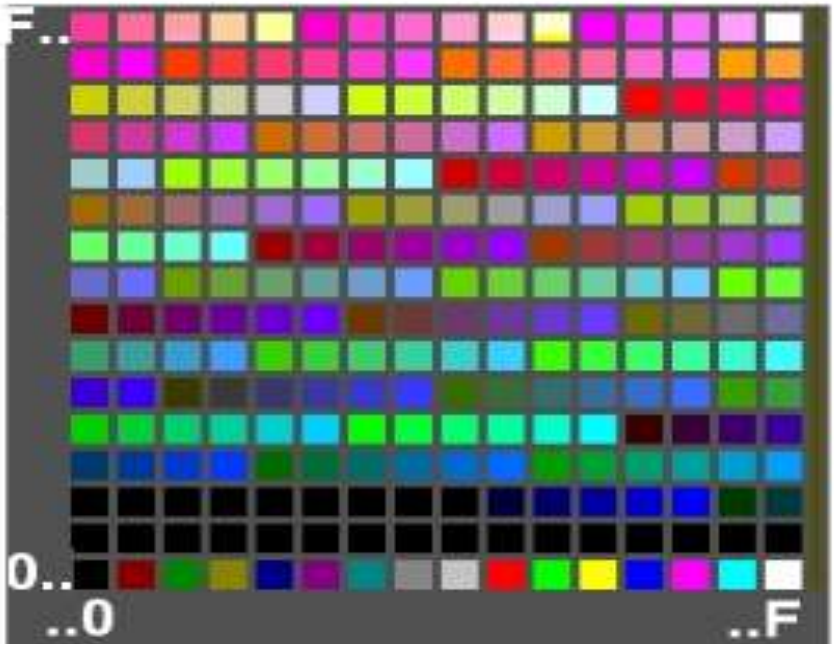
GIF using the (LZW) lossless data compression technique to reduce the file size without degrading the visual quality.

Gif was patented in 1985. By 2004 all the relevant patents had expired.



# GIF Files

- Pictures can contain at most 256 different colours
- File format defines a “palette” of 24-bit colours
- Each pixel stored as an 8-bit index into this palette
- Use 8-bits (1 byte) per pixel
- LZW Compression – lossless
- Good for images with limited set of colours such as logos, web buttons etc
- Also support animation
- Supported by all web browsers
- Possible copyright problems



# PORTABLE NETWORK GRAPHICS - PNG

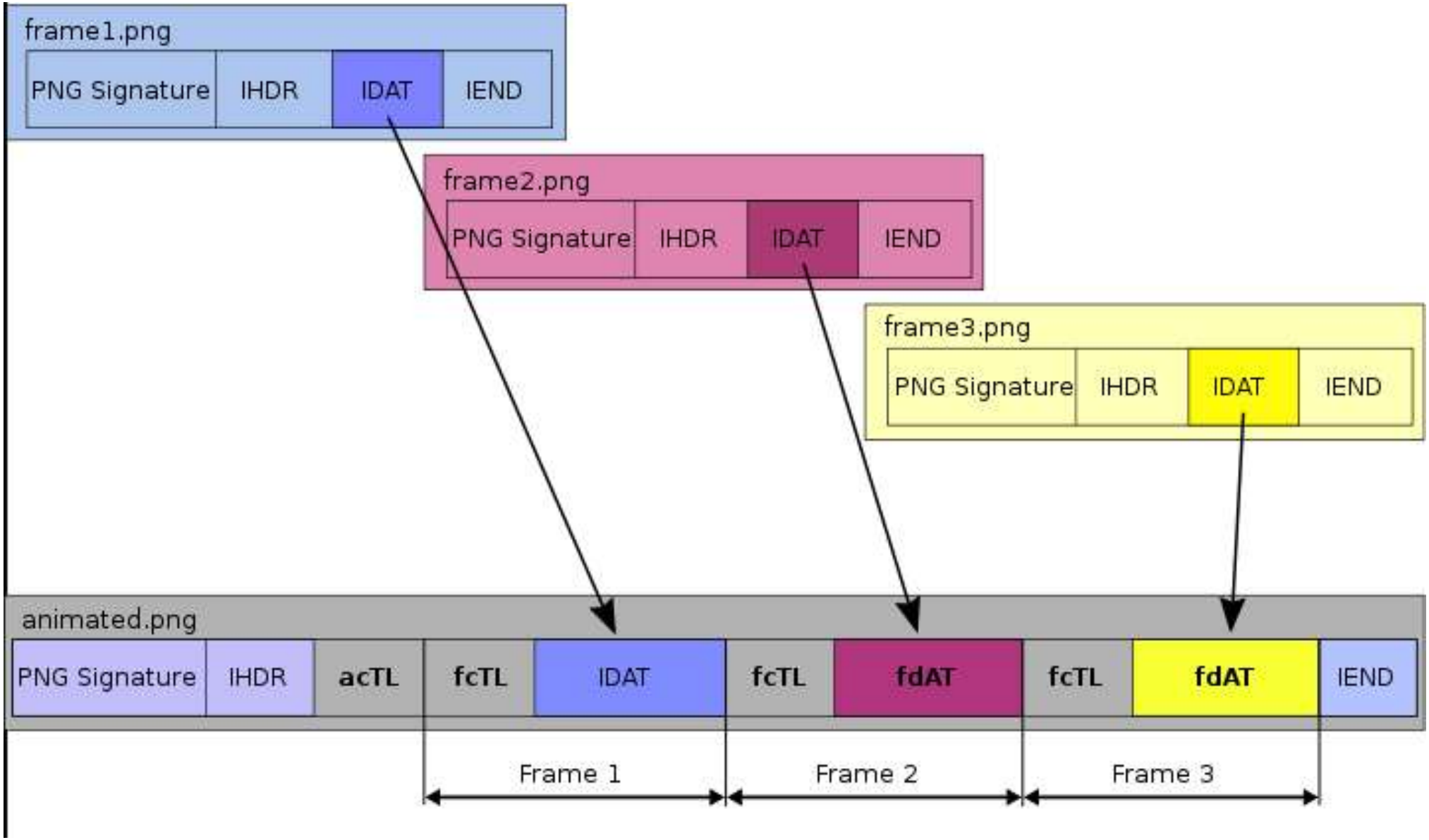
Portable Network Graphics (PNG) is a raster graphics file format that supports lossless data compression.

PNG was created as an improved, non-patented replacement for Graphics Interchange Format (GIF), and is the most widely used lossless image compression format on the Internet.

**Portable Network Graphics**

A PNG image with an 8-bit transparency channel, overlaid onto a checkered background, typically used in graphics software to indicate transparency.

| | |
|---|---|
| **Filename extension** | `.png` |
| **Internet media type** | `image/png` |
| **Type code** | PNGf<br>PNG |
| **Uniform Type Identifier (UTI)** | public.png |
| **Magic number** | `89 50 4e 47 0d 0a 1a 0a` |
| **Developed by** | PNG Development Group (donated to W3C) |
| **Initial release** | 1 October 1996; 20 years ago |
| **Type of format** | lossless bitmap image format |


frame1.png
PNG Signature
IHDR
IDAT
IEND
frame2.png
PNG Signature
IHDR
IDAT
IEND
frame3.png
PNG Signature
IHDR
IDAT
IEND
animated.png
PNG Signature
IHDR
acTL
fcTL
IDAT
fcTL
fdAT
fcTL
fdAT
IEND
Frame 1
Frame 2
Frame 3

# TAGGED IMAGE FILE FORMAT - TIFF

TIFF is an extensible format, often used for storing uncompressed digital photographs, and for interchange of images.

600 dpi
TIFF file

72 dpi
TIFF file

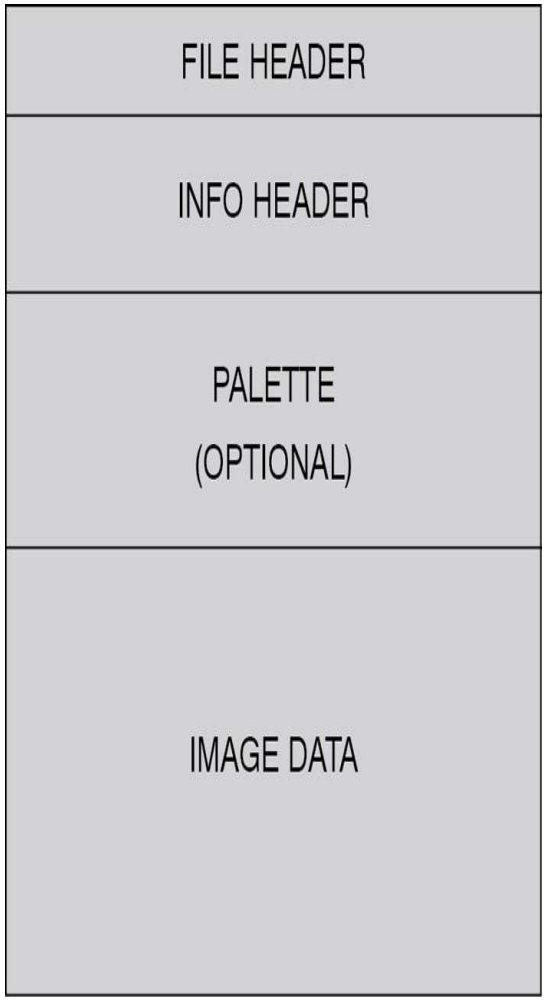
72 dpi
JPEG file
(medium quality)

# **BMP FILE** FORMAT

**bitmap** image **file** or device independent **bitmap** (DIB) **file** format, is a raster graphics image **file** format used to store **bitmap** digital images, independently of the display device (such as a graphics adapter), especially on Microsoft Windows

**.BMP** or **.DIB** (*Device Independent Bitmap*).

A **BMP file** is an uncompressed raster image comprised of a rectangular grid of pixels. It contains a file header (bitmap identifier, file size, width, height, color ...



# SUMMARY