江西理工大學信息工程学院
JIANGXI UNIVERSITY OF SCIENCE AND TECHNOLOGY SCHOOL OF INFORMATION ENGINEERING

Digital Image Processing

数字图像处理

Lecture 18:

IMAGE COMPRESSION

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Digital Image Processing

LECTURE 18: Image Compression

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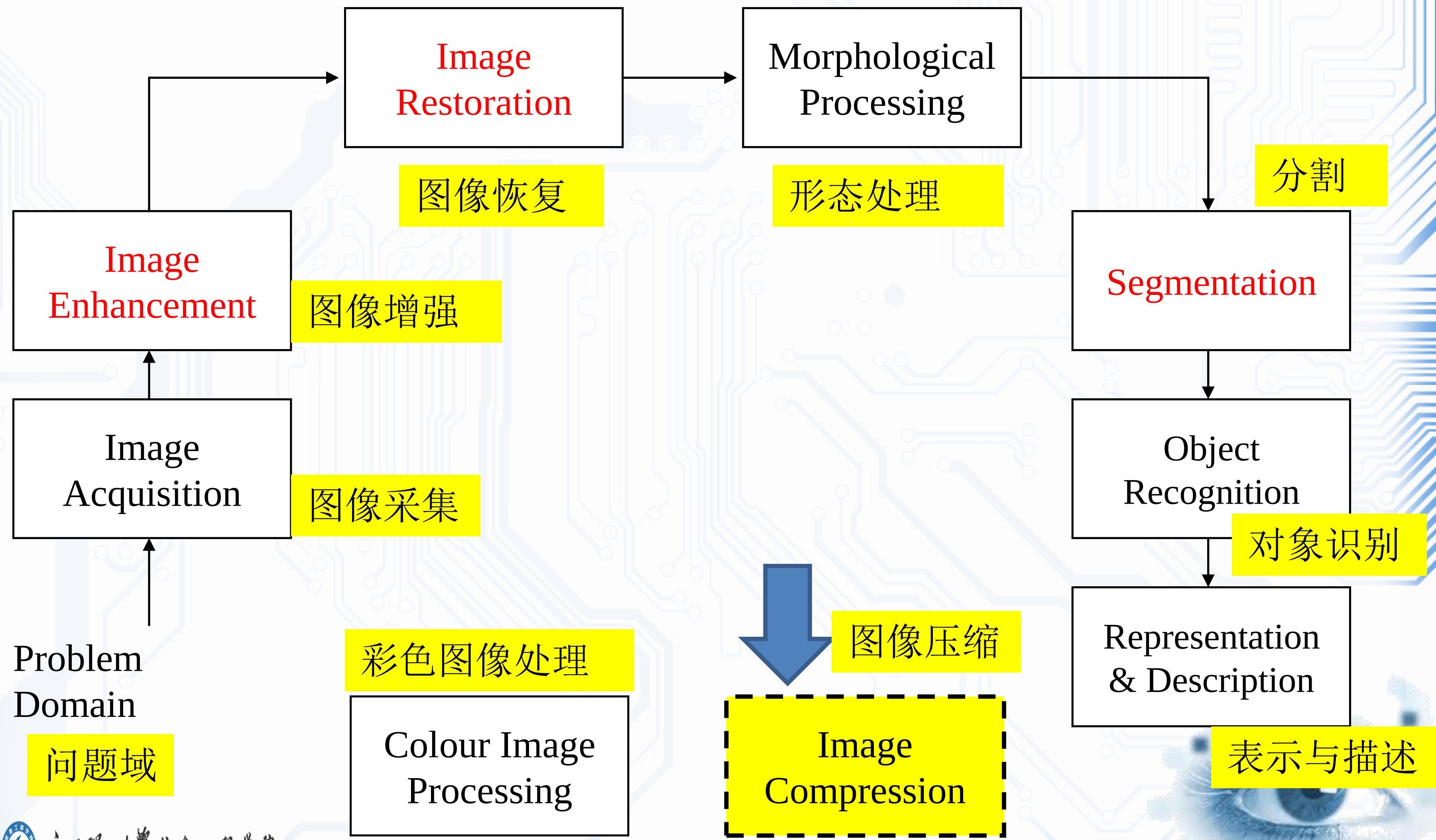
Agenda

IMAGE COMPRESSION 图像压缩

1. What/Why Image Compression? 什么/为什么图像压缩?
2. Compression Fundamentals 压缩基本原理
3. Data Redundancies 数据冗余性
4. Compression techniques 压缩技术
5. What is Data Compression? 什么是数据压缩?
6. **Lossy Compression** 有损压缩
7. Lossless Compression 无损压缩

Key Stages in Digital Image Processing:



Can you see the Differences?

你能看出区别吗？ Nǐ néng kàn chū qūbié ma?

Image Compression

图像压缩 Túxiàng yāsuō

- Image compression is needed to reduce the storage requirement and to increase the transmission efficiency such as transmission rate and noise immunity.

为了降低存储需求，提高传输效率，如传输速率和抗噪声能力，需要对图像进行压缩。

- Image compression refers to the process of reducing the amount of data required to represent a given digital image - removal of redundant data (data redundancy).

图像压缩是指减少表示给定数字图像所需的数据量的过程-去除冗余数据(数据冗余)。

Size-270 KB Size-22 KB

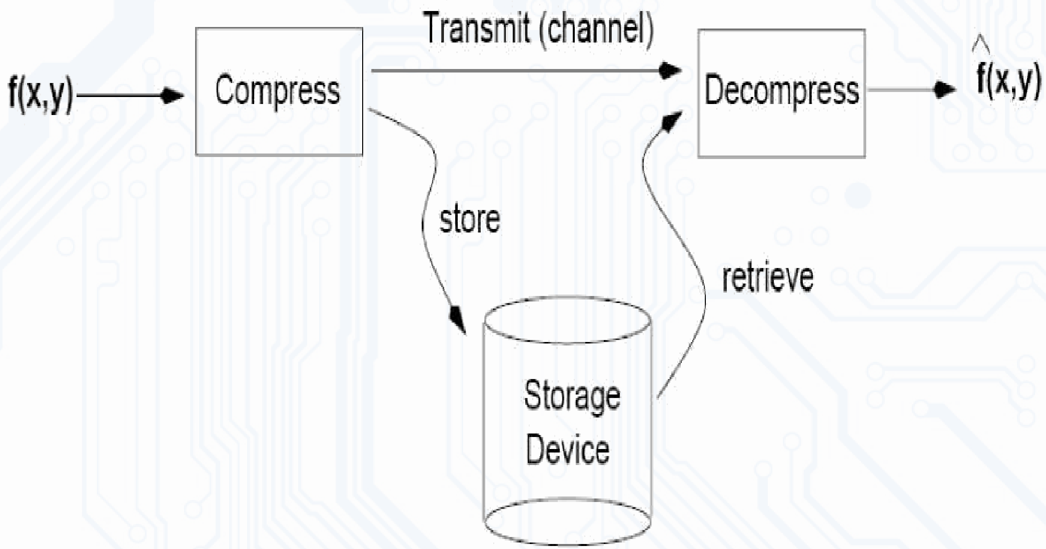
•“Without Compression a CD store only 200 Pictures or 8 Seconds Movie”

没有压缩CD存储只有200图片或8秒电影

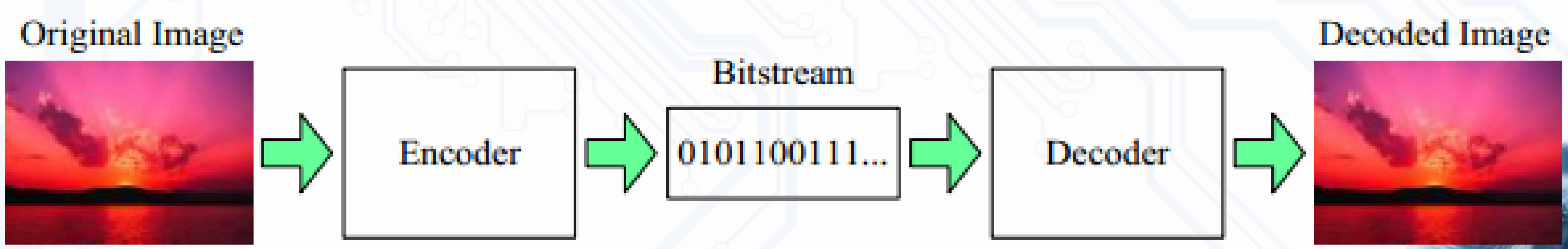
What is Image Compression?

什么是图像压缩？ Shénme shì túxiàng yāsuō?

- Image compression is the process of reducing the amount of data required to represent an image



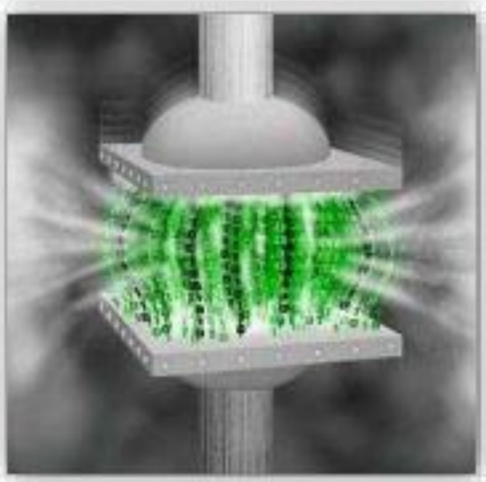
图像压缩是减少表示图像所需的数据量的过程



Why Compression?

为什么要压缩?

Storage



Ease of Transmission

Compression Fundamentals

压缩基础

- Image compression involves reducing the size of image data files, while retaining necessary information

  图像压缩涉及减少图像数据文件的大小，同时保留必要的信息

- Retaining necessary information depends upon the application

  保留必要的信息取决于申请

- Image segmentation methods, which are primarily a data reduction process, can be used for compression

  图像分割方法主要是一个数据缩减过程，可以用于压缩

- The ratio of the original, uncompressed image file and the compressed file is referred to as the compression ratio

  原始的、未压缩的图像文件与压缩文件的比率称为压缩比

Why Compression?

为什么要压缩?

- Now, consider the transmission of video images, where we need multiple frames per second, If we consider just one second of video data that has been digitized at 640x480 pixels per frame, and requiring 15 frames per second for interlaced video, then:

现在，考虑视频图像的传输，我们需要每秒多帧。如果我们考虑一秒的视频数据以640x480像素每帧数字化，交错视频需要每秒15帧，那么:

- Waiting 35 seconds for one second's worth of video is not exactly real time.

为了一秒的视频而等待35秒并不是真正的时间。

EXAMPLE 10.1.6: To transmit one second of interlaced video that has been digitized at 640x480 pixels:

$$\frac{(640 \times 480 \times 15\ frames/\mathbf{sec})(24 bits/pixel)}{3 \times 1024 \times 1024 bits/\mathbf{sec})} \approx 35\ \mathbf{sec}\ onds$$

- Even attempting to transmit uncompressed video over the highest speed Internet connection is impractical

甚至试图通过最高速度的互联网连接传输未压缩的视频也是不切实际的

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Compression techniques

压缩技术

- Compression techniques are broadly classified into two:

  Lossless Compression & Lossy Compression.

- Lossless compression techniques:

Compression techniques where perfect (lossless) reconstruction is possible.

- Variable length coding
- LZW coding
- Bit-plane coding
- Predictive coding-DPCM

压缩技术大致分为两种：
无损压缩和有损压缩。
无损压缩技术：
可以实现完美（无损）重建的压缩技术。
■ 可变长度编码
■ LZW 编码
■ 位平面编码
■ 预测编码-DPCM

Compression techniques

压缩技术

- Lossy compression techniques 有损压缩技术：

Compression techniques where perfect (lossless) reconstruction is not possible. 不可能实现完美(无损)重构的压缩技术

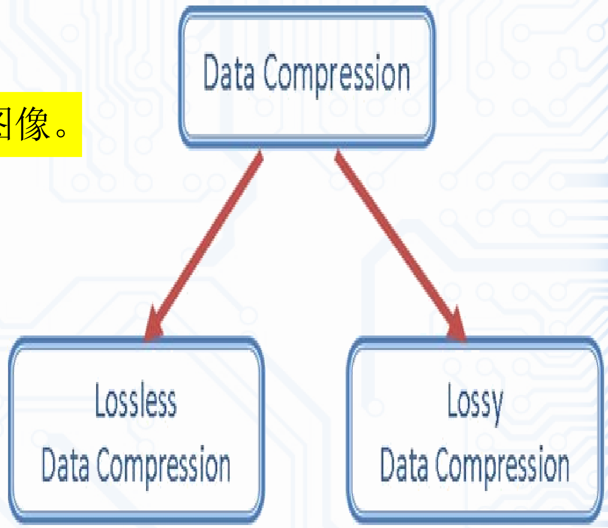
- – Transform coding 变换编码
- – Wavelet coding 小波编码
- – Basics of image compression standards: JPEG 图像压缩标准基础知识:JPEG
- – Basics of vector quantization: MPEG 矢量量化基础:MPEG

压缩技术

Compression Techniques

•**Lossless** image compression is a compression algorithm that allows the original image to be perfectly reconstructed from the original data.

无损图像压缩是一种压缩算法，可以从原始数据中完美重建原始图像。



•**Lossy** image compression is a type of compression where a certain amount of information is discarded which means that some data are lost and hence the image cannot be decompressed with 100% originality.

有损图像压缩是一种压缩类型，其中丢弃了一定数量的信息，这意味着丢失了一些数据，因此无法以 100% 的原创性对图像进行解压缩。

Compression Techniques

压缩技术

Compression techniques are broadly classified into two:

- Lossless Compression
- Lossy Compression.

压缩技术大致分为两种:
无损压缩
有损压缩。

Lossless compression techniques: Compression techniques where perfect (lossless) reconstruction is possible.

- Variable length coding
- LZW coding
- Bit-plane coding
- Predictive coding-DPCM

无损压缩技术:使完美(无损)重构成为可能的压缩技术。
--可变长度编码
--LZW编码
--位平面编码
--预测coding-DPCM

Lossy compression techniques: Compression techniques where perfect (lossless) reconstruction is not possible.

- Transform coding
- Wavelet coding
- Basics of image compression standards: JPEG
- Basics of vector quantization: MPEG

有损压缩技术:不可能实现完美(无损)重构的压缩技术。
--变换编码
--小波编码
--图像压缩标准基础知识:JPEG
--矢量量化基础:MPEG

Compression Techniques

压缩技术

- Image Compression
  - Lossy
    - Fractal Coding
    - Lossy Predictive Coding
    - Vector Quantization
    - Block Truncation Coding
    - DCT
    - DWT
  - Lossless
    - Lossless Predictive Coding
    - LOCO-I
    - PBWT
    - Variable Block Size Segmentation

- Fractal Image Compression 分形图像压缩
  - Huber FIC
  - Region Based Fractal Image Compression Using Heuristic Search
  - Fractal technique based Human Visual System (HVS)
  - Using Genetic Algorithm Fractal IC
  - DCT Inner Product
  - Fractal image compression with simple classification scheme infrequency domain

- DCT
  - DCT Spectral Similarity Strategy
  - 3D Discrete Cosine Transform Coder
  - Warped Discrete Cosine Transform

Compression Techniques

压缩技术

- 图像压缩
  - 有损
    - 分形编码
    - 损耗预测编码
    - 矢量量化
    - 块Tnuncation编码
    - DC
    - D
  - 无损的
    - 无损的预测编码
    - LOOO I
    - PBW :
    - 可变块大小分割
- 分形图像压缩
  - 胡伯 Fic
  - 基于启发式Searca的区域分形图像压缩
  - 基于分形技术的人类视觉系统
  - 基于遗传算法的分形集成电路
  - DCT内积
  - 分形图像压缩与简单的分类方案
- DCT
  - DCT谱相似策略
  - 3D离散余弦变换编码器
  - 弯曲离散余弦变换

压缩技术

Compression Techniques

Image Compression using Coding of Wavelet

- Embedded Zero Wavelet Algorithm (EZW)
- Wavelet Compression of Chromosome Images
- Predictive Embedded Zero tree Wavelet (PEZW)
- Wavelet-Based Compression Scheme for Satellite Images
- Embedded Compression on Wavelet Pixel sorting and classification
- Line and Reduced Memory based Wavelet Image Compression (WIC)
- Fast Adaptive Wavelet Packet (FAWP)
- Compression Using BSP Scheme and Geometric Wavelets

基于小波编码的图像压缩

- 嵌入式零小波算法(EZW)
- 染色体图像的小波压缩
- 预测嵌入式零树小波(PEZW)
- 基于小波的卫星图像压缩方案
- 基于小波像素分类的嵌入式压缩
- 基于线性和精简内存的小波图像压缩(WIC)
- 快速自适应小波包
- 压缩U型BSP格式和cemetric小波

压缩技术

Compression Techniques

Lossless Image Compression

- Lossless Image Compression with Variable Block Size Segmentation
- Dynamic Image Data in Spatial and Temporal Domain
- LOCO-I Lossless Algorithm for images
- Lossless image compression Using GAP and burrows-wheeler transformation
- Lossless Compression using multiple array technique for medical images
- Algorithm based on Texture and Multiple Template
- 3D lossless method based on region growing

Image Compression Based on Fuzzy Algorithms

- Fuzzy Vector Quantization
- Fuzzy algorithms for learning vector quantization

无损图像压缩,

- 可变块大小分割的无损图像压缩
- 动态图像数据的空间和时间域
- 图像LOCO-I无损算法
- 基于GAP和钻轮变换的无损图像压缩
- 医学图像的多阵列无损压缩技术
- 基于纹理和多重模板的算法
- 基于区域增长的无损耗方法

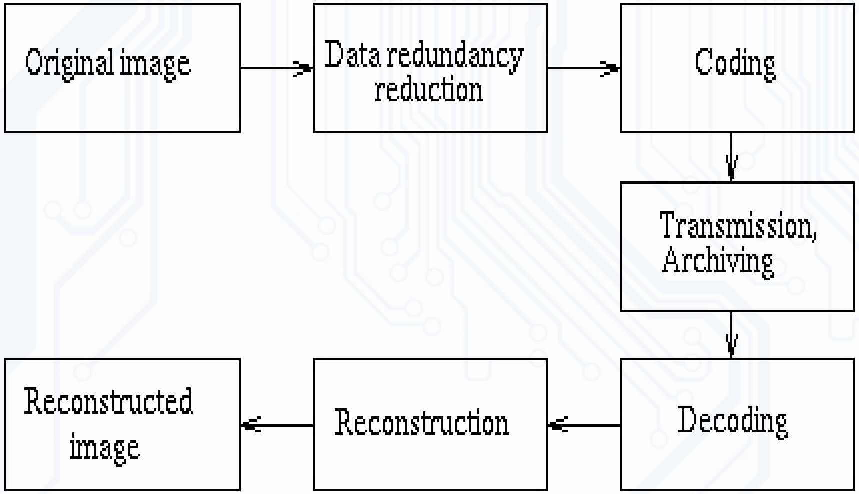
基于模糊算法的图像压缩

- 模糊矢量量化
- 学习向量量化的模糊算法

什么是数据压缩？

What is Data Compression?

- Data compression is the process of diminishing the storage size of any data or file so that it consumes less space on the disk.
- It is the technique of modifying, restructuring, encoding and converting the schema or instance of any data to reduce its size.
- In simple words, it is converting the file in such a way that its size is reduced to a maximum extent.
- Data compressions is also known as bit-rate reduction or source coding.

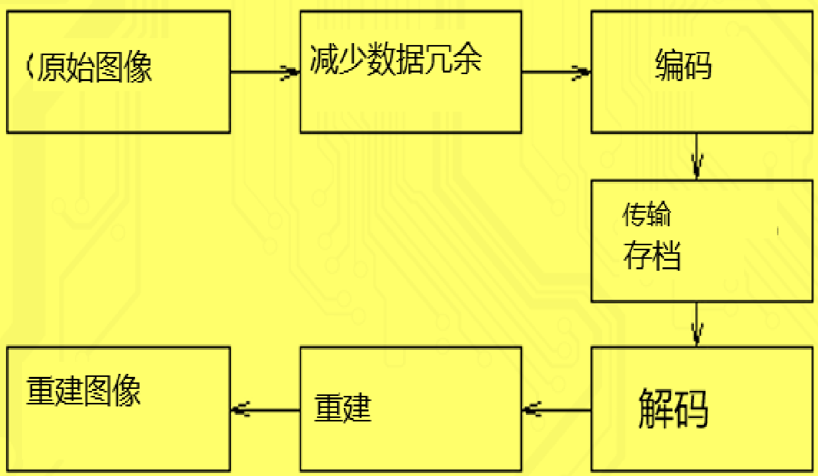


An example of an image that is converted or compressed to reduce its size without losing the ability to reconstruct the image.

什么是数据压缩?

What is Data Compression?

- 数据压缩是减少任何数据或文件的存储大小，以减少磁盘空间的过程
- 它是一种修改、重组、编码和转换任何数据的模式或实例以减少其大小的技术
- 简单地说，它转换文件的方式是将文件的大小减少到最大限度。
- 数据压缩也被称为比特率降低或源编码。



一种经过转换或压缩以缩小其尺寸而又不丧失重建图像能力的图像的示例

Now, the question here is why there is a need for data compression?

现在，这里的问题是为什么需要数据压缩?

有两个主要原因。存储

- There are two primary reasons for the same.
  - **Storage** – it helps in reducing the size of data that is required to store it on the disk

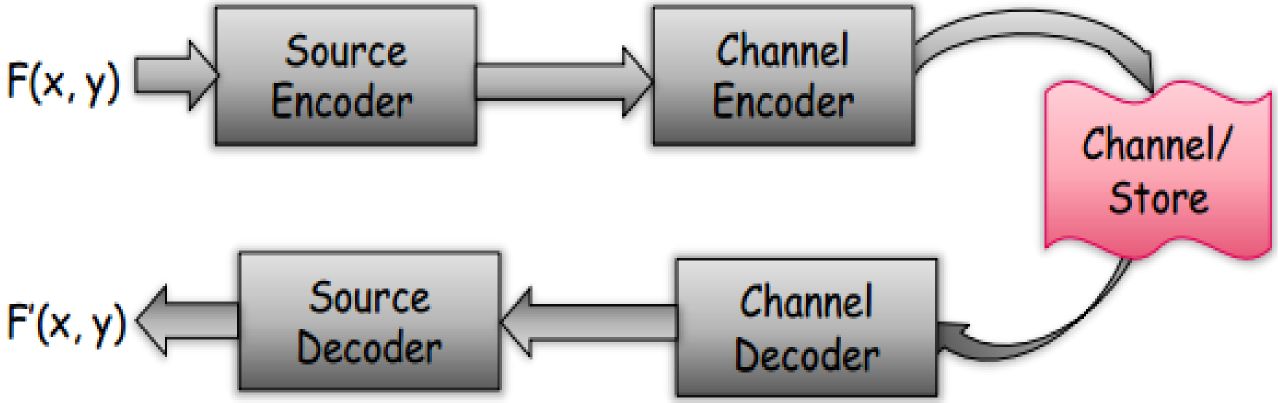
    - 它有助于减少将其存储在磁盘上所需的数据大小时间

  - **Time** – saves time in data transmission as the size is reduced to an extent

    - - 节省数据传输时间，因为大小减少到一定程度

Image Compression General Models

图像压缩通用模型



- Some image Compression Standard
  - JPEG-Based on DCT
  - JPEG 2000-Based on DWT
  - GIF-Graphics Interchange Format etc.

一些图像压缩标准
JPEG-基于 DCT
JPEG 2000-基于 DWT
GIF-图形交换格式等。

Data ≠ Information

数据≠信息

- Data and information are not synonymous terms.
- 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.
- Image compression is an irreversible process.

Some Transform used in Image Compression

DCT-Discrete Cosine Transform

DWT-Discrete wavelet Transform etc.

Data ≠ Information

数据≠信息

- 数据和信息不是同义词。
- 数据是传递信息的手段。
- 数据压缩的目的是减少表示给定数量信息所需的数据量，同时保留尽可能多的信息。
- 图像压缩是一个不可逆的过程。

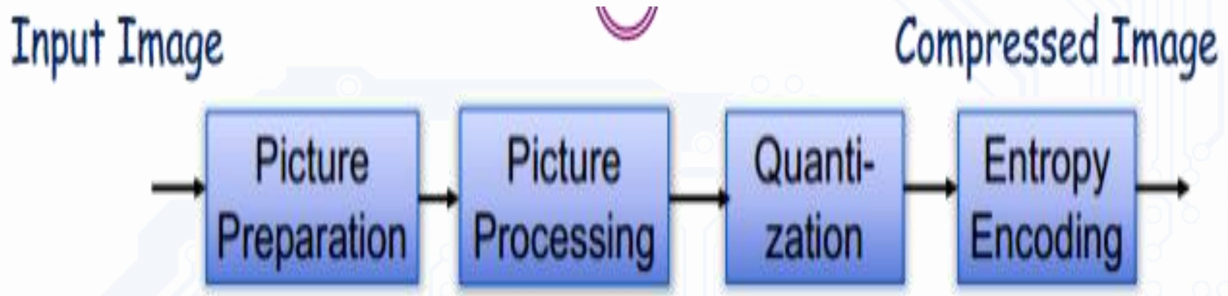
图像压缩中使用的一些变换

DCT-Discrete余弦变换

dwt离散小波变换等。

Compression Steps

压缩步骤



- Preparation: analog to digital conversion. 准备:模数转换。

Processing: transform data into a domain easier to compress.

- 处理:将数据转换为更容易压缩的域。

Quantization: reduce precision at which the output is stored.

- 量化:降低存储输出的精度。

Entropy Encoding: remove redundant information in the resulting data stream

熵编码:去除结果数据流中的冗余信息

Image Compression-Lossy or Lossless

图像压缩-有损或无损

But its resolution or features should be unchanged for human perception. 但它的分辨率或特征对于人类的感知应该是不变的。

- Relative Data Redundancy Rd of the first data set is Rd=1-1/CR
- Where CR-Compression Ratio=n1/n2.
- n1 and n2 denote the nos. of information carrying units in two data
- sets that represent the same information.

第一个数据集的相对数据冗余Rd=1-1/CR
CR-Compression率= n1、n2。

n1和n2表示两个数据中携带信息的单位数
表示相同信息的集合。

In Digital Image Compression, the basics data redundancies are

- Coding Redundancy
- Inter pixel Redundancy
- Psycho-visual Redundancy

在数字图像压缩中，基本的数据冗余是
编码冗余
像素间冗余
Psycho-visual冗余

Data Redundancies

数据冗余

Compression algorithms are developed by taking advantage of the redundancy that is inherent in image data.

利用图像数据固有的冗余特性，开发了压缩算法。

Various amount of data may be used to represent the same amount of information. In such case if two sets of data, one being large and another being small, represent the same information, then the large amount of data is said to contain data that either provide no relevant information or simply repeat the same information.

可以使用不同数量的数据来表示相同数量的信息。在这种情况下，如果两组数据(一组大数据，另一组小数据)代表相同的信息，那么大量数据就被认为包含不提供相关信息或只是重复相同信息的数据。

This is known as data redundancy.There are three types of data redundancies, namely, **the interpixel redundancy,the psychovisual redundancy the coding redundancy.**

这就是所谓的数据冗余。数据冗余有三种类型，即像素间冗余、心理视觉冗余和编码冗余

Data Redundancies

数据冗余

编码冗余：当用于表示图像的数据没有以最佳方式使用时发生

1. **Coding Redundancy:** Occurs when the data used to represent the image is not utilized in an optimal manner

像素间冗余：由于相邻像素往往高度相关，在大多数图像中，亮度水平不是快速变化的，而是逐渐变化的。

2. **Interpixel Redundancy:** Occurs because adjacent pixels tend to be highly correlated, in most images the brightness levels do not change rapidly, but change gradually.

像素间冗余：对人类视觉系统来说，某些信息比其他类型的信息更重要

3. **Psychovisual Redundancy:** Some information is more important to the human visual system than other types of information

Trade Off: Quality vs. Compression

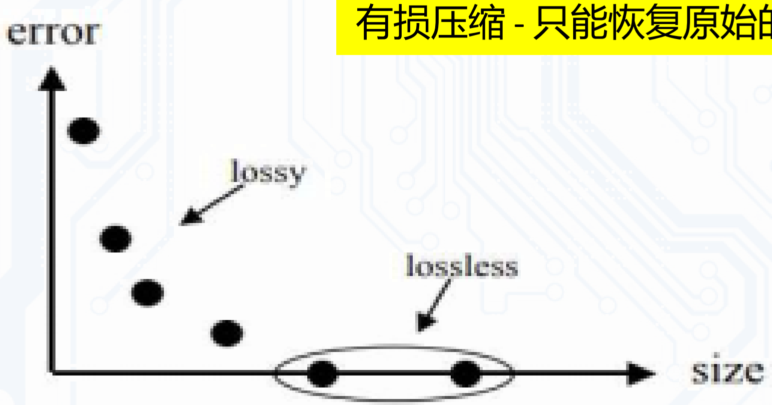
权衡：质量与压缩

- **Lossless Compression** (Information Preserving) - Original can be recovered exactly. Higher quality,bigger.

无损压缩（信息保存)- 可以准确恢复原件。更高质量，更大

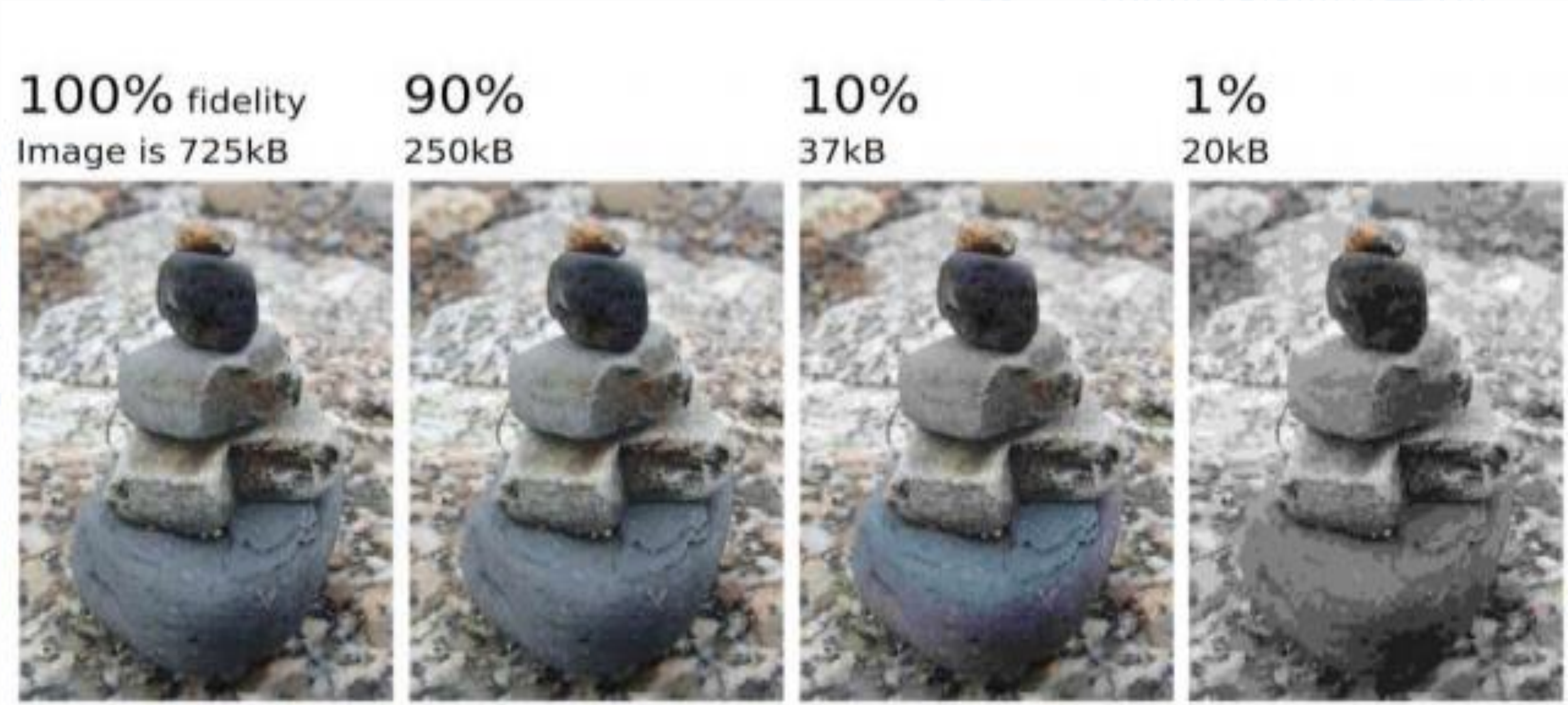
- **Lossy Compression-** Only an approximation of the original can be recovered. Lower quality, smaller.

有损压缩 - 只能恢复原始的近似值。质量较低，体积较小。



图像压缩

Image Compression



Data Redundancy

数据冗余

Measures of data redundancy: **Relative Data Redundancy** and **Compression Ratio**.

- Let n_1 and n_2 be the number of information-carrying units in two data sets that represent the same information.
- Then the relative data redundancy, R_D is defined as

数据冗余度量:相对数据冗余度和压缩比。
设n1和n2为表示相同信息的两个数据集中携带信息的单位数。
然后定义相对数据冗余度RD为

$$R_D = 1 - \frac{1}{C_R} \quad \text{where} \quad C_R = \frac{n_1}{n_2} \quad \text{is called the compression ratio.}$$

i) If $n_2=n_1$, then $C_R=1$ and $R_D=0$ (no redundant data in n_2)
ii) If $n_2 << n_2$, then $C_R= \infty$ and $R_D=1$ (highly redundant data in n_2)
iii) If $n_2 >> n_2$, then $C_R=0$ and $R_D=- \infty$ (more irrelevant data in n_2)
iv) Hence C_R and R_D lie in the open intervals, $(0,\infty)$ and $(-\infty,1)$, respectively.

Data Redundancy

图像压缩

Interpixel Redundancy 像素间冗余

- If, in an image, the value of a pixel can be reasonably predicted from the value of its neighbours, then the image is said to contain interpixel redundancy.
- The correlation statistics such as auto correlation coefficients are used to measure the interpixel redundancy.

- 如果在一幅图像中，一个像素的值可以从它的邻居的值合理地预测，那么该图像被称为包含像素间冗余。
- 利用自相关系数等相关统计量来度量像素间冗余度。

Data Redundancy

图像压缩

Psychovisual Redundancy 心理视觉冗余

- If an image contains certain information that is less relative important than the other information in normal visual processing, then the image is said to contain psychovisual redundancy.

如果图像包含某些信息在正常视觉处理中不如其他信息相对重要，则称该图像包含心理视觉冗余。

Data Redundancy

图像压缩

Coding Redundancy

编码冗余

- If the gray levels of an image are coded in a way that uses more code symbols than absolutely necessary to represent each gray level, the resulting image is said to contain coding redundancy.
- The histogram of the image is a useful tool to provide means of reducing the coding redundancy. Let r_k be a discrete random variable in the interval [0,1] representing the set of gray levels in an image. Let n_k represent the number of pixels with the gray level r_k in the image.
- Then the probability of occurrence of a gray level, r_k is defined as

$$p_r(r_k) = \frac{n_k}{n}, \mathrm{k} = 0,1,2,\ldots,\mathrm{L}-1$$

- If the number of bits required to represent each gray l evel, rk is l(rk) then the average code length is

$$L_{av} = \sum_{k=0}^{L-1} p_r(r_k) l(r_k)$$

Data Redundancy

图像压缩

如果对图像的灰度级进行编码，使用了比绝对必要的更多的编码符号来表示每个灰度级，则得到的图像被称为包含编码冗余。

图像的直方图是一个有用的工具，提供了减少编码冗余的手段。设r为区间[0,1]内的离散随机变量，表示图像的灰度等级集合。设nk表示图像中灰度级为k的像素数

然后定义一个灰度级发生的概率Ik为

$$p_r(r_k) = \frac{n_k}{n}, k = 0,1,2,\dots,L-1$$

如果表示每个灰度级所需的比特数为1(rk)，则平均码长为

$$L_{av} = \sum_{k=0}^{L-1} p_r(r_k) l(r_k)$$

Data Redundancy

图像压缩

Coding Redundancy Example: An 8-level image has a gray-level distribution as shown in Table 4.1. Compute the percentage of redundancy in Code 1.

编码冗余示例:8级图像灰度分布如表4.1所示。在代码1中计算冗余的百分比。

r_k	$p_r(r_k)$	Code 1	$l_1(r_k)$	Code 2	$l_2(r_k)$
$r_0 = 0$	0.19	000	3	11	2
$r_1 = 1/7$	0.25	001	3	01	2
$r_2 = 2/7$	0.21	010	3	10	2
$r_3 = 3/7$	0.16	011	3	001	3
$r_4 = 4/7$	0.08	100	3	0001	4
$r_5 = 5/7$	0.06	101	3	00001	5
$r_6 = 6/7$	0.03	110	3	000001	6
$r_7 = 1$	0.02	111	3	000000	6

Data Redundancy 数据冗余

The average length of the code for Code 1 代码1的平均长度

$$L_{1av}=\sum_{k=0}^{7}p_r(r_k)l(r_k)=3\sum_{k=0}^{7}p_r(r_k)=3$$

The average length of the code for Code 2 代码2的平均长度

$$L_{2av}=\sum_{k=0}^{7}p_r(r_k)l(r_k)=\sum_{k=0}^{7}[(0.19\times 2)+(0.25\times 2)+(0.21\times 2)+(0.25\times 2)+$$
$$+(0.16\times 3)+(0.08\times 4)+(0.06\times 5)+(0.03\times 6)+(0.02\times 6)]=2.7$$

Hence the compression ratio

因此压缩比

$$C_R=\frac{L_{1av}}{L_{2av}}=\frac{3}{2.7}=1.11.$$

Hence the relative data redundancy

因此存在相对数据冗余

$$R_D=1-\frac{1}{C_R}=1-\frac{1}{1.11}=0.099.$$

Hence the percentage of data redundancy

因此数据冗余的百分比

$$R_D\times 100=9.9\%.$$

Coding Redundancy 编码冗余

- Length of the code words (e.g., 8-bit codes for grey value images) is larger than needed. 代码字的长度（例如，灰度值图像的 8 位代码）大于所需的长度。
- Coding redundancy is associated with the representation of information.
  编码冗余与信息的表示有关
- The information is represented in the form of codes. 信息以代码的形式表示
- If the gray levels of an image are coded in a way that uses more code symbols than absolutely necessary to represent each gray level then the

如果图像的灰度级以使用比表示每个灰度级绝对必要的更多的代码符号的方式编码，则结果图像被称为包含编码冗余。

Coding Redundancy 编码冗余

- Let n_k be the number of times that intensity $k \in [0, L-1]$ occurs in an $M \times N$ image, and r_k a random variable representing intensities. Probability of r_k:

$$p_r(r_k) = \frac{n_k}{MN}, \quad k = 0, 1, \ldots, L-1$$

- If r_k is represented by $l(r_k)$ bits, the average number of bits per pixel is:

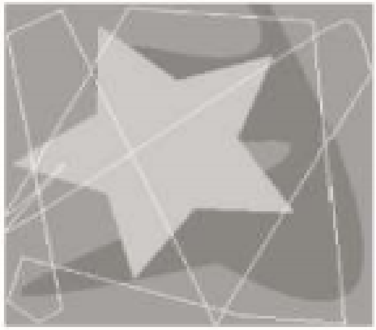
$$L_{\text{avg}} = \sum_{k=0}^{L-1} l(r_k)\, p_r(r_k)$$

- Total number of bits: $MN\, L_{\text{avg}}$.
  For a fixed-length code of m bits: $L_{\text{avg}} = m$.

Coding Redundancy

编码冗余

Measuring the Information
I=Log[1/P(E)]
=-log P(E)



r_k	$p_r(r_k)$	Code 1	$l_1(r_k)$	Code 2	$l_2(r_k)$
$r_{87} = 87$	0.25	01010111	8	01	2
$r_{128} = 128$	0.47	10000000	8	1	1
$r_{186} = 186$	0.25	11000100	8	000	3
$r_{255} = 255$	0.03	11111111	8	001	3
r_k for $k \neq 87, 128, 186, 255$	0	—	8	—	0

- Code 1: fixed-length 8-bit code: $L_{avg} = 8$ bits
- Code 2: variable-length code: $L_{avg} = 1.81$ bits
  $C = \frac{8}{1.81} = 4.42$, $R = 1 - \frac{1}{4.42} = 0.774$ (77.4% of original data is redundant)

Measuring Information

测量信息

- These methods, from information theory, are not limited to images, but apply to any digital information.
- Here uses "symbols" instead of "pixel values" and "sources" instead of images

这些方法来自信息论，不限于图像，也适用于任何数字信息。
这里使用"符号"而不是"像素值"和"源"而不是图像

Given a zero-memory source of statistically independent random events (source symbols) $\{a_j\}$ occurring with probability $P(a_j)$, $j = 1, 2, \ldots J$.

- Source entropy: $H = -\sum_{j=1}^{J} P(a_j) \log P(a_j)$
- Estimated source entropy for L-level image:

$$\tilde{H} = -\sum_{k=0}^{L-1} p_r(r_k) \log_2 p_r(r_k)$$

- $\tilde{H}$ is the minimum number of bits per pixel needed to code the image.

Shanon’s First Theorem

香农第一定理

$$H = -\sum p(x) \log p(x)$$

- Shanon looked at group of n consecutive source symbols with a single code word (rather than one code word per source symbol) and showed that-

Shanon观察了一组n个连续的源符号，其中只有一个编码字(而不是每个源符号都有一个编码字)，并证明-

$$\left| \frac{L_{avg}}{n} \right| = H$$

- Where Lavg is the average number of code symbols required to represents all n symbols groups.

其中Lavg是表示所有n个符号组所需代码符号的平均数量。

Coding Redundancy 编码冗余

r_k	$p_r(r_k)$	Code 1	$l_1(r_k)$	Code 2	$l_2(r_k)$
$r_{87} = 87$	0.25	01010111	8	01	2
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$r_{255} = 255$	0.03	11111111	8	001	3
r_k for $k \neq 87, 128, 186, 255$	0	—	8	—	0

- Code 2: variable-length code: = 1.81 bits
- Entropy

$$\tilde{H} = -(0.25\log_2 0.25 + 0.47\log_2 0.47 + 0.25\log_2 0.25 + 0.03\log_2 0.03) = 1.6614 \text{ bits}$$

-

Is there a code attaining the lower bound of 1.6614 bits/pixel ?

Two common algorithms: Huffman coding and LZW coding

Fidelity Criteria 保真标准

Input image $f(x,y)$, approximation $\hat{f}(x,y)$, both of size $M \times N$.

- Root-mean square error:

$$e_{\text{rms}} = \left[\frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left(\hat{f}(x,y) - f(x,y) \right)^2 \right]^{\frac{1}{2}}$$

- Mean-square signal-to-noise ratio:

$$\text{SNR}_{\text{rms}} = \frac{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \hat{f}(x,y)^2}{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left(\hat{f}(x,y) - f(x,y) \right)^2}$$

RMS Error

均方根误差

- The rms of the three images are 5.17, 15.67, and 14.17

三幅图像的均方根分别为 5.17、15.67 和 14.17

Image Compression

图像压缩

Value	Rating	Description
1	Excellent	An image of extremely high quality, as good as you could desire.
2	Fine	An image of high quality, providing enjoyable viewing. Interference is not objectionable.
3	Passable	An image of acceptable quality. Interference is not objectionable.
4	Marginal	An image of poor quality; you wish you could improve it. Interference is somewhat objectionable.
5	Inferior	A very poor image, but you could watch it. Objectionable interference is definitely present.
6	Unusable	An image so bad that you could not watch it.

Inter-Pixel Redundancy:

像素间冗余：

Inter-Pixel Spatial Redundancy:

- Inter-pixel redundancy is due to the correlation between the neighboring pixels in an image.
- The value of any given pixel can be predicated from the value of its neighbors (Highly Correlated).
- The information carried by individual pixel is relatively small.
- To reduce inter-pixel redundancy the difference between adjacent pixels can be used to represent an image.

Inter-Pixel Temporal Redundancy

- Inter-Pixel temporal redundancy is the statistical correlation between pixels from successive frames in video sequence.
- Temporal redundancy is also called inter-frame redundancy.
- Removing a large amount of redundancy leads to efficient video compression.

•Algorithm: Run Length Coding

Inter-Pixel Redundancy:

像素间冗余:

Inter-Pixel空间冗余:

- 像素间冗余是由于图像中相邻像素之间的相关性
- 任何给定像素的值都可以通过它的邻居(高度相关)的值来预测。
- 单个像素所携带的信息量相对较小。
- 为了减少像素间的冗余，可以利用相邻像素之间的差异来表示图像。

Inter-Pixel时间冗余

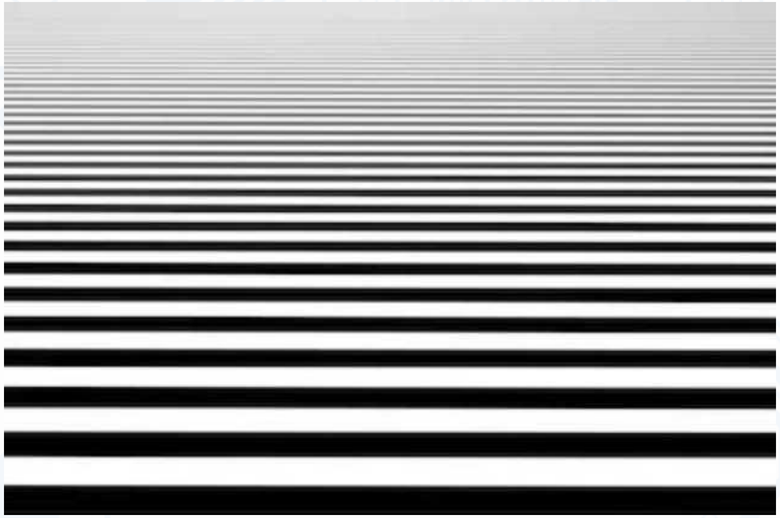
- 像素间时间冗余是视频序列中连续帧像素间的统计相关性。
- 时间冗余也称为帧间冗余。
- 去除大量冗余，可以实现高效的视频压缩。

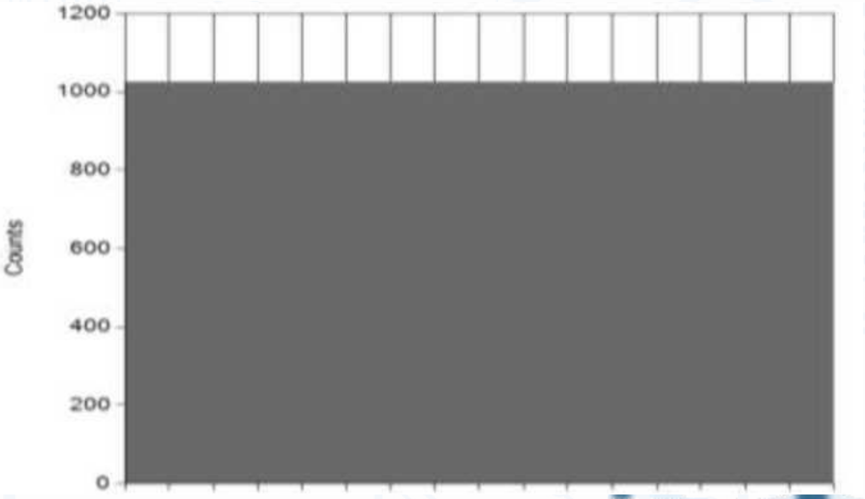
算法:运行长度编码

Spatial Redundancy 空间冗余

- Its Histogram (Ignore White Background)
- Just variable length coding is not sufficient?

其直方图(忽略白色背景)
仅仅变长编码是不够的





0 255

运行长度算法

Run Length Algorithm

Lets Discuss ***(During Lecture!)***

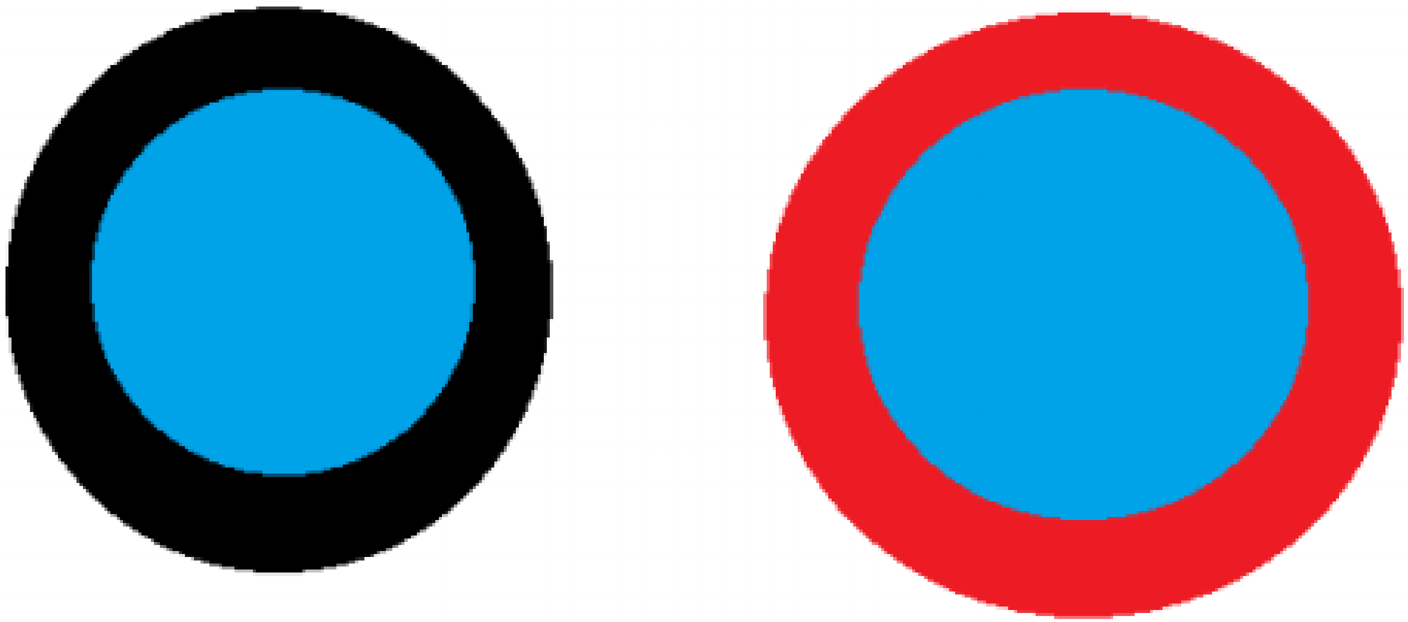
- Consider one Binary Image
- Its vector representation
- Size without compression
- Size after run length algorithm

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

让我们讨论（在讲座中！）
考虑一个二值图像它的向量表示大小没有压缩运行长度算法后的大小

Which have higher intensity (Centre Circle)?

哪个强度更高（中心圆）？

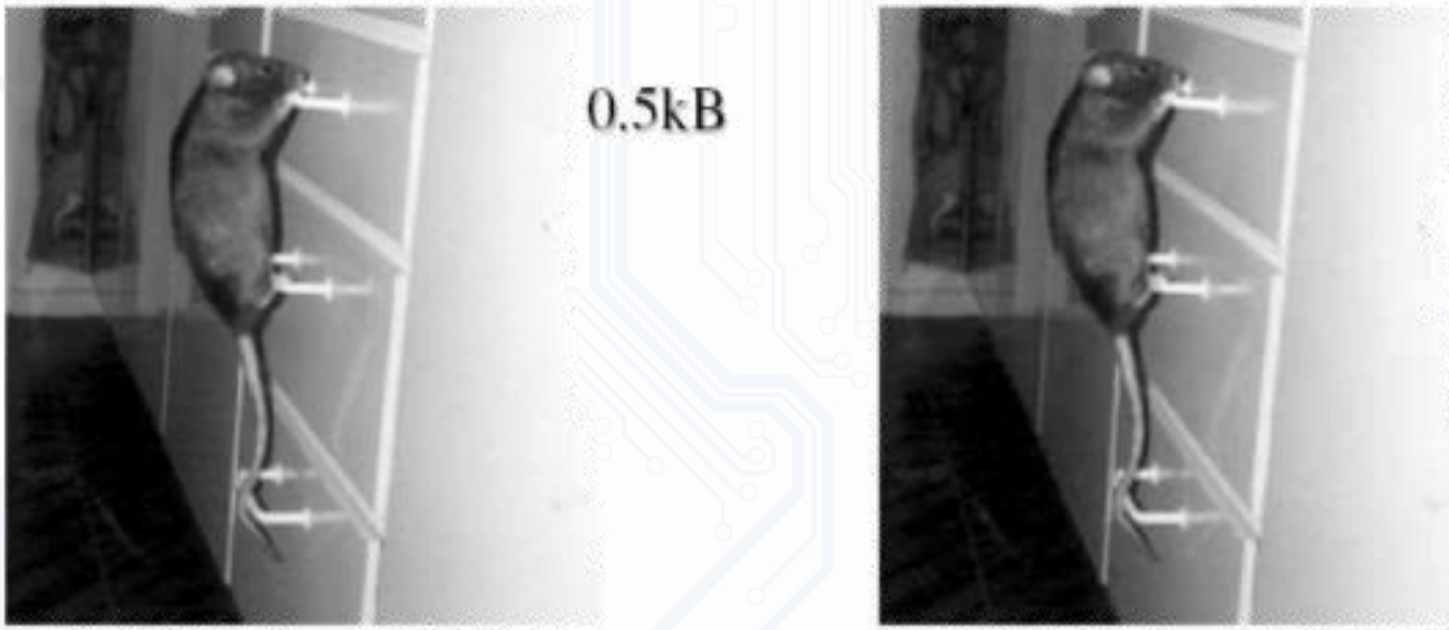


心理视觉冗余

Psychovisual Redundancy

If the image will only be used for visual observation (i.e. illustrations on the web etc), a lot of the information is usually psycho-visually redundant. It can be removed without changing the visual quality of the image. This kind of compression is usually irreversible.

如果图像只用于视觉观察(即。网页上的插图等)，很多信息通常是心理视觉冗余的。它可以在不改变图像视觉质量的情况下被删除。这种压缩通常是不可逆的。

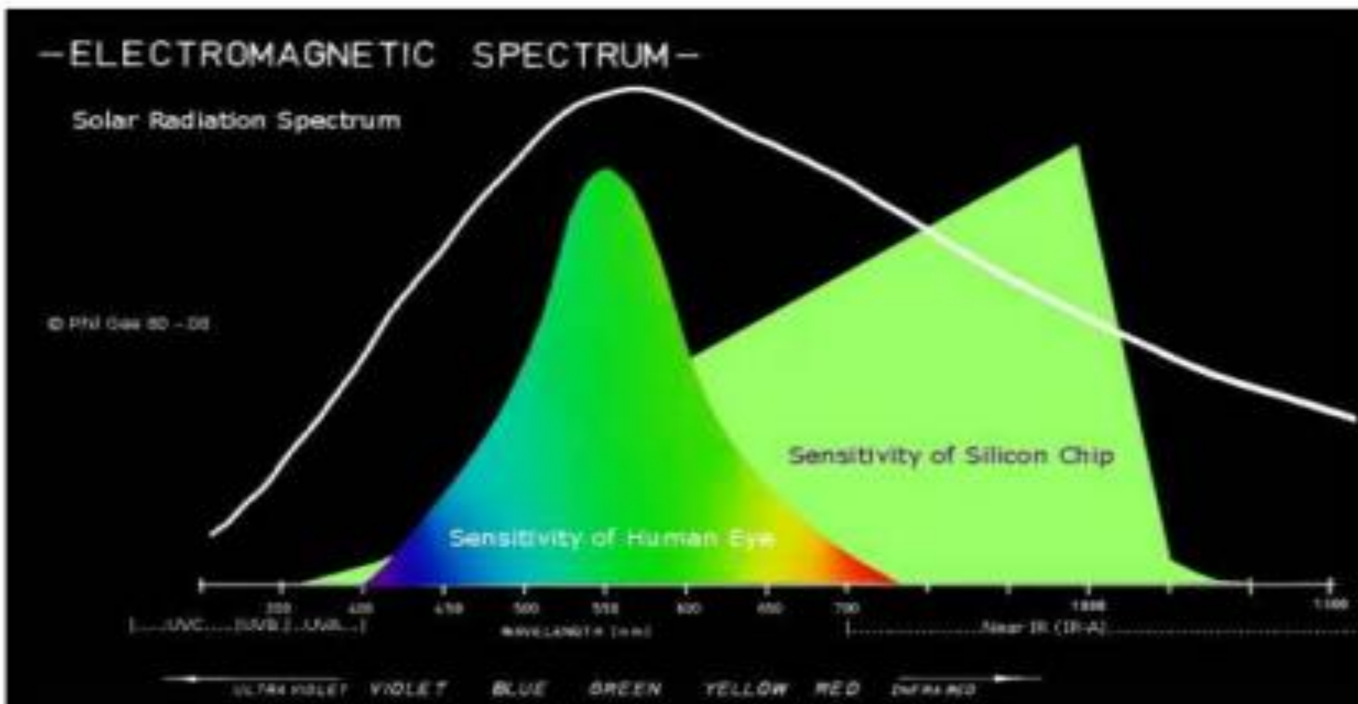


心理视觉冗余

Psycho visual Redundancy

The Psychovisual redundancies exist because human perception does not involve quantitative analysis of every pixel or luminance value in the image.

•It’s elimination is real visual information is possible only because the information itself is not essential for normal visual processing.



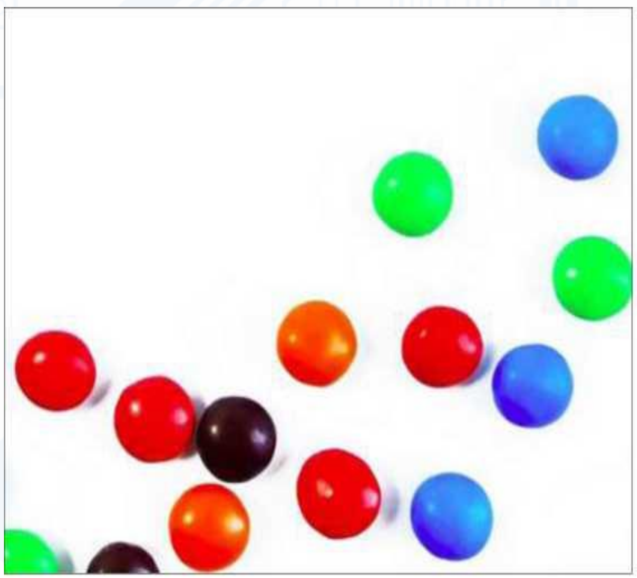
心理视觉冗余的存在是因为人类的感知不涉及对图像中每个像素或亮度值的定量分析。

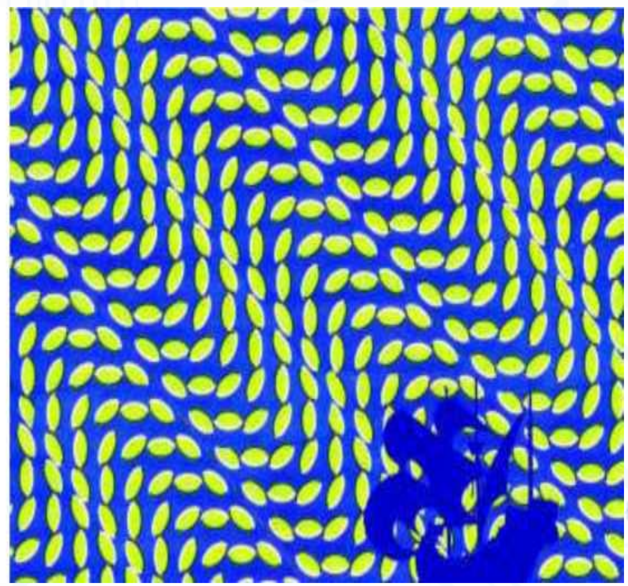
它的消除是真实的视觉信息是可能的只是因为信息本身对正常的视觉处理不是必需的

心理视觉冗余

Psycho visual Redundancy

- We’re more sensitive to differences between dark intensities than bright ones. Encode log(intensity) instead of intensity.
- We’re more sensitive to differences of intensity in green than red or blue.
- Use variable quantization: devote most bits to green, fewest to blue.





我们对黑暗强度的差异比对明亮强度的差异更敏感。编码日志(强度)而不是强度。

相对于红色或蓝色，我们对绿色的强度差异更敏感。

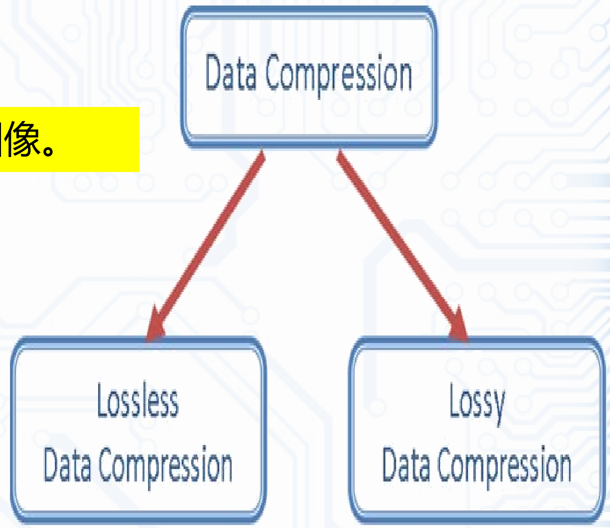
使用变量量化:将大部分比特赋给绿色，将最小比特赋给蓝色。

Review once more: Compression Techniques

压缩技术

•**Lossless** image compression is a compression algorithm that allows the original image to be perfectly reconstructed from the original data.

-无损图像压缩是一种压缩算法，可以从原始数据中完美重建原始图像。



•**Lossy** image compression is a type of compression where a certain amount of information is discarded which means that some data are lost and hence the image cannot be decompressed with 100% originality.

-有损图像压缩是一种压缩类型，其中丢弃了一定数量的信息，这意味着丢失了一些数据，因此无法以100% 的原创性对图像进行解压缩。

有损压缩

Lossy Compression

- Lossy compression is a technique that involves the elimination of a specific amount of data. It helps in reducing the file size to a great extent without any noticeable thing.
- **Also, once the file is compressed, it cannot be restored back to its original form as the data from the file is significantly reduced.**
- **This technique is much more useful when the quality of the file is not essential. Additionally, it helps to save much space on the disk to store the data.**
- Lossy compression is not useful when the quality of the file is essential. Besides, if there's any further analysis to be processed on the record, this method is not ideal.
- This method is generally used for audio and video compression, where there is a significant amount of data loss, and even users cannot recognize it.

有损压缩

Lossy Compression

- 有损压缩是一种涉及到消除特定数量数据的技术。它有助于在没有任何明显的东西的情况下，在很大程度上减少文件大小。
- 此外，一旦文件被压缩，它就不能恢复到原来的形式，因为来自文件的数据大大减少了。
- 当文件的质量不是至关重要的时候，这种技术更有用。此外，它还有助于节省磁盘上存储数据的大量空间。
- 当文件质量至关重要时，有损压缩是没有用的。此外，如果有任何进一步的分析需要在记录上处理，这种方法并不理想。
- 这种方法通常用于音频和视频压缩，在这类压缩中存在大量的数据丢失，甚至用户无法识别

Example of lossy compression: JPEG image

有损压缩示例：JPEG 图像

"Compressed image (left) shows blocking artifacts compared to the original image (right) as a result of the JPEG compression scheme used."

压缩后的图像(左)显示了与原始图像(右)相比的块伪影，这是使用JPEG压缩方案的结果

Lossless Compression

无损压缩

- Lossless compression is a technique that involves only a certain amount of elimination of data.
- **This technique also helps in reducing the file size, but not to the greater extent as that of lossy compression. Instead, in this method, if the file is compressed, it can be restored back to its original form.**
- Further, the quality of the data is not compromised; hence, the reduction in size is not much.
- Lossless compression is not useful when you want reduced size for extra storage.
- Also, if there is any further analysis to be performed on the file, lossless compression is not beneficial.
- It is useful for maintaing the originality of files by eliminating only unwanted data.
- **This technique is commonly used for text files, sensitive documents, and confidential information.**

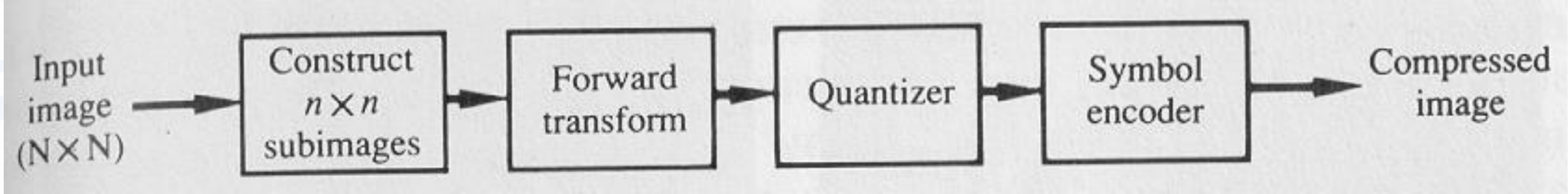
无损压缩是一种仅涉及一定数量的数据消除的技术。 这种技术也有助于减小文件大小，但不会像有损压缩那样大。 相反，在此方法中，如果文件被压缩，则可以将其恢复为原始形式。 此外，数据的质量不会受到影响； 因此，尺寸的减少并不多。 当您想要减少额外存储的大小时，无损压缩没有用。 此外，如果要对文件执行任何进一步分析，无损压缩也无济于事。 通过仅删除不需要的数据来维护文件的原创性非常有用。 这种技术通常用于文本文件、敏感文档和机密信息。

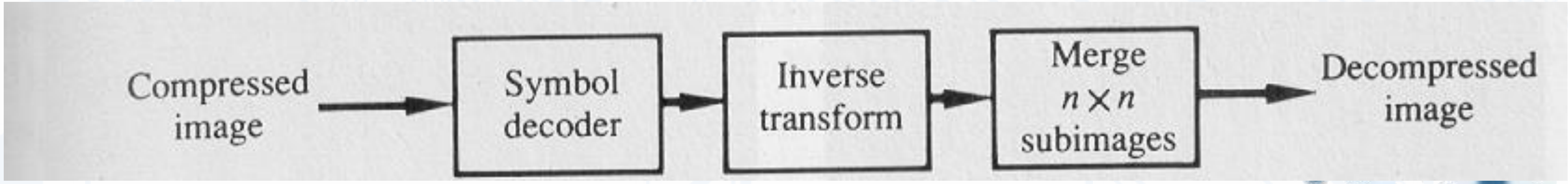
Lossy Compression

无损压缩

- Transform the image into some other domain to reduce interpixel redundancy.

将图像变换到其他域以减少像素间冗余





Taxonomy of Lossless Methods

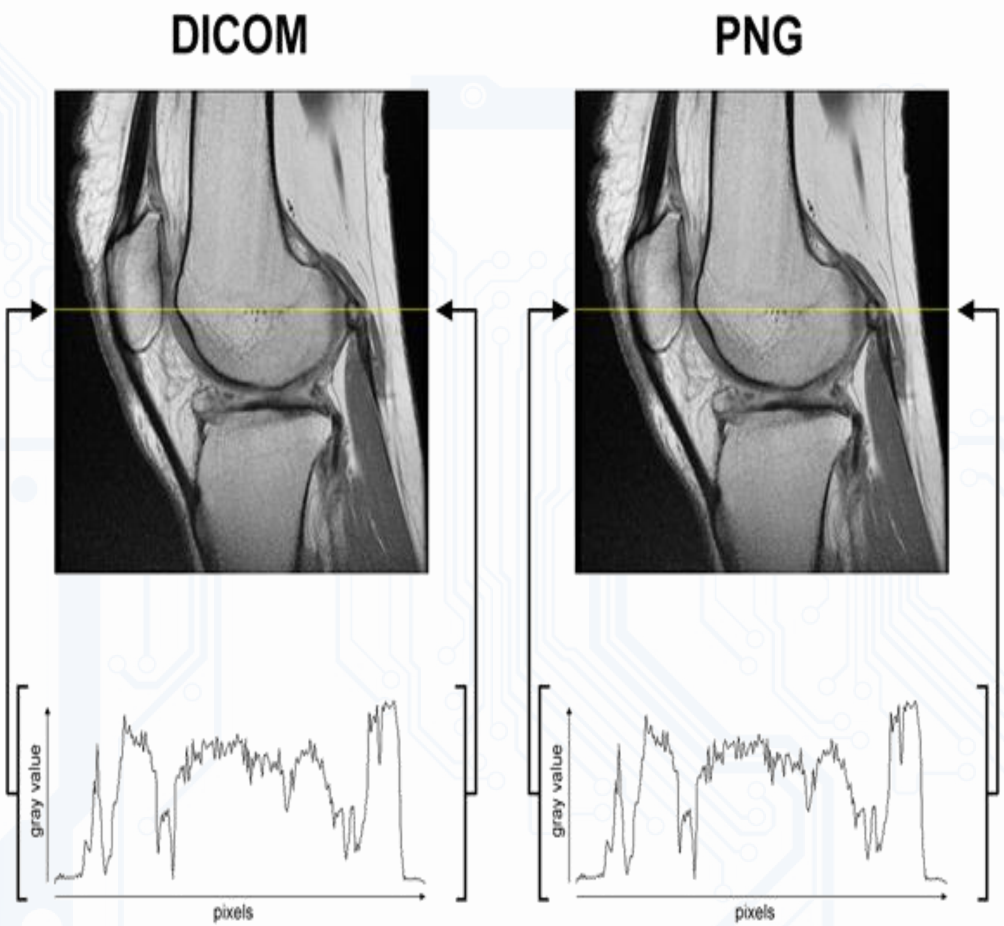
无损编码技术（熵编码）

Lossless coding techniques (Entropy Coding)

- 重复序列编码 — Repetitive Sequence Encoding
  - RLE
- 无损预测编码 — Lossless Predictive coding
  - DPCM
- 统计编码 — Statistical Encoding
  - Huffman Coding
  - Arithmetic (or Range) Coding
  - LZW Coding
- 位平面编码 — Bit-plane Encoding
  - Bit-plane Encoding

Example of lossless compression: PNG image

无损压缩示例：PNG 图像



"The original image (left) is identical to the compressed image (right). It is represented by the identical graphs at the bottom that show the grey values for the pixels in each column is the same between the two images."

"原始图像（左）与压缩图像（右）相同。 它由底部的相同图形表示，显示每列中像素的灰度值在两幅图像之间是相同的。"

有损压缩和无损压缩的区别

Difference between Lossy and Lossless Compression

Basis	Lossy Compression	Lossless Compression
Definition	Lossy compression is a technique that involves the elimination of a specific amount of data. It helps in reducing the file size to a great extent without any noticeable thing	**Lossless compression is a technique that involves only a certain amount of elimination of data. This technique also helps in reducing the file size, but not to the greater extent**
Compression Ratio	High	**Low**
File Quality	Low	**High**
Elimination of Data	Even the necessary data is also removed which isn't noticeable	**Only some specific amount of unwanted data is removed**
Restoration	Cannot restore its original form	**Can restore its original form**
Loss of Information	This technique involves some loss of information	**This technique doesn't include any loss of information**
Data Accommodation	More data accommodation	**Less data accommodation**
Distortion	Files are distorted	**No distortion**
Data holding capacity	More	**Less**
Algorithms Used	Transform coding, DCT, DWT, fractal compression, RSSMS	**RLW, LZW, Arithmetic encoding, Huffman encoding, Shannon Fano coding**
File Types	JPEG, GIF, MP3, MP4, MKV, OGG, etc.	**RAW, BMP, PNG, WAV, FLAC, ALAC, etc.**

Which One to Use? 使用哪一个?

Although both are the types of data compression, each can be useful under different situations

- . Like, lossy compression helps in reducing the file size, which means it is helpful to those who have vast amounts of data stored on the database.
- So, this technique is useful in storing the data with a much-diminished size. Also, for webpages files of such lower size is beneficial for faster loading.
- Further, this process doesn’t allow any after analysis of the data once the compression is completed. Also, the file cannot be restructured in its original form as it involves the loss of data.

比如，有损压缩有助于减小文件大小，这意味着它对那些在数据库中存储了大量数据的人很有帮助。
因此，这种技术在存储大小大大减少的数据时非常有用。同样，对于网页文件来说，这样小的尺寸有利于更快的加载。
此外，这个过程不允许压缩完成后对数据进行任何分析。此外，由于涉及数据丢失，文件不能以其原始形式重新构造。

- Unlike lossy compression, lossless compression doesn’t involve any loss of data.
- Neither the quality of data is compromised, nor the size of data is excessively reduced. It keeps the original format so it can be restored, and further operation can be performed.
- This method is helpful for those who need to access the data back again without compromising its quality.

与有损压缩不同，无损压缩不涉及任何数据丢失。
既不影响数据的质量，也不过分减少数据的大小。它保留原始格式，以便可以恢复它，并可以执行进一步的操作。
这种方法对那些需要在不影响数据质量的情况下再次访问数据的人很有帮助

Final Review 总复习

- **Both lossy compression and lossless compression helps in the compression of data in their unique way.** 有损压缩和无损压缩都以其独特的方式帮助压缩数据。
- While lossy compression is useful to store data by compromising the data, lossless compression doesn't. 有损压缩可以通过损害数据来存储数据，而无损压缩则不行。
- Lossless compression technique is beneficial for maintaing the originality of data, and lossy compression, on the other hand, doesn't. 无损压缩技术有利于保持数据的原创性，有损压缩则相反。
- Both the methods are helpful in database management, to identify and compress files accordingly. 这两种方法都有助于数据库管理，以便识别和压缩相应的文件。

- 请帮我翻译部分的朋友鼓掌
- Qǐng bāng wǒ fānyì bùfèn de péngyǒu gǔzhǎng

江西理工大学

Jiangxi University of Science and Technology

信息工程学院

School of information engineering

Digital Image Processing

THANK YOU

"BE HUMBLE. BE HUNGRY. AND ALWAYS BE THE HARDEST WORKER IN THE ROOM."

MAY-BRITT MOSER
Nobel Prize in Physiology or Medicine 2014

“I learned at an early age that work makes you happy.”

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- • Digital Image Processing, Using MATLAB, by Rafael C. Gonzalez, Richard E. Woods, and Steven L. Eddins
- • Image Processing Toolbox, For Use with MATLAB (MATLAB's documentation)--available through MATLAB's help menu or online at:
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