EBU5303

Multimedia Fundamentals

Introduction to Data Compression

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Learning Objectives

- Explain what data compression is
- Discuss why it is important
- Appraise how it can be done
- Describe examples of compression techniques for image, music and video data

Agenda

- What is data compression?
- Why is it important?
- How can it be done?
- Examples of information compression techniques

Image Credits: erhui1979 / Getty Images

What is Data Compression?

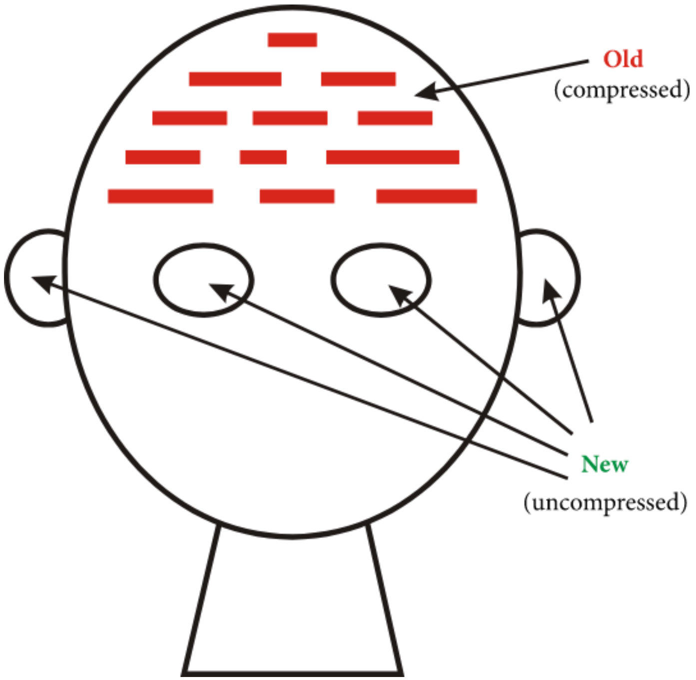
- It is the process of reducing the amount of data needed for the storage or transmission of a given piece of information.

Illustration: Lisa Hornung/iStockPhoto

- It allows the storage and sharing of images, videos, and music with computers and mobile phones.

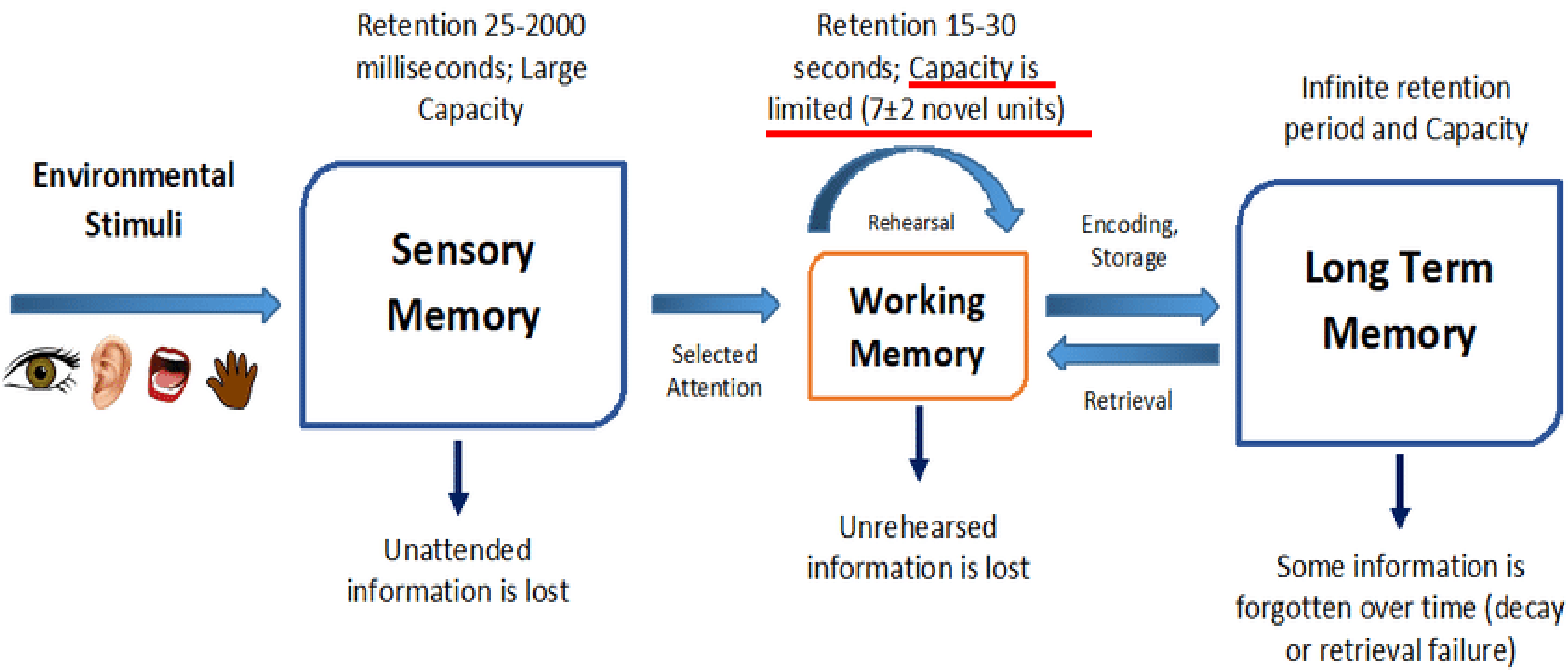
- **zip, rar, pdf, jpeg, mpeg, mp3 …**

Information Compression in the Brain



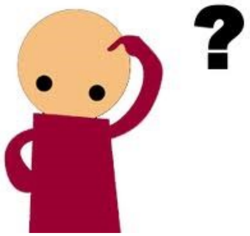
From "Information Compression as a Unifying Principle in Human Learning, Perception, and Cognition" by Gerard Wolff. Illustration available via license: [CC BY 4.0]

Chunking to Increase Working Memory Capacity



Atkinson-Shiffrin 3-stage model of human memory (1968)

Question



What does the word “Beijing” evoke to you?

Natural Language: a Data Compressor?

Beijing

busy

traditional

capital

Uni

ultramodern

home

the world's most populous national capital city

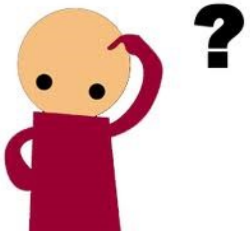
at the northern tip of the roughly triangular North China Plain, which opens to the south and east of the city

One of the oldest cities in the world

Visual stimuli compression in the brain

Attneave's cat (1954)

Question



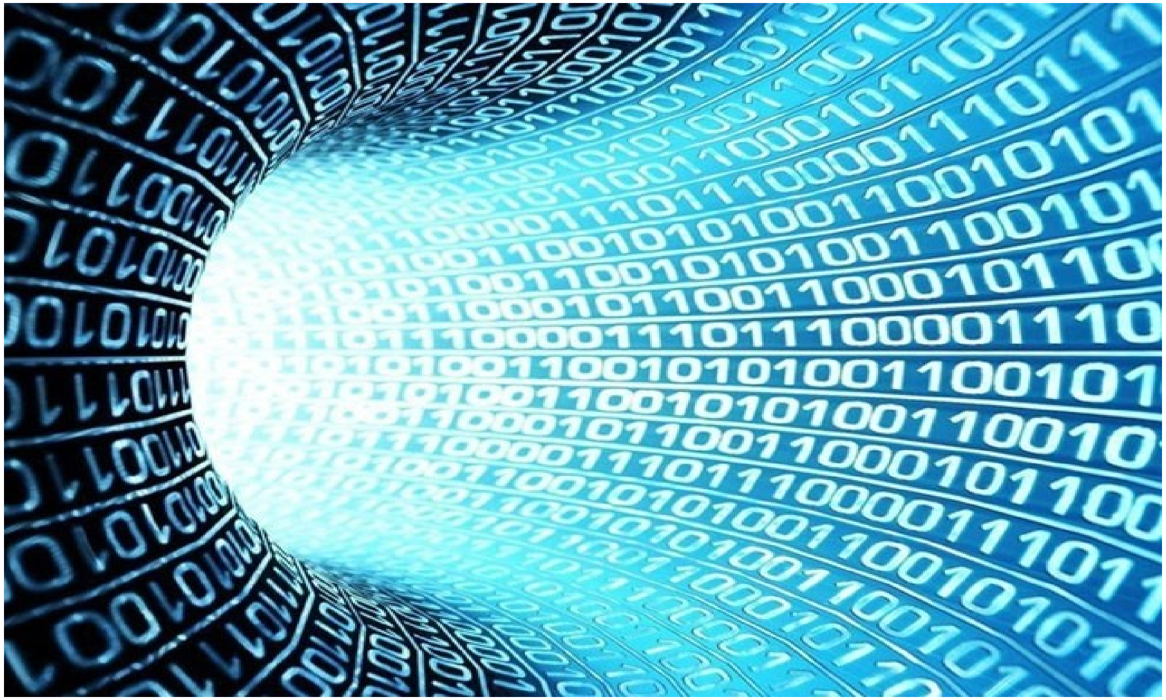
How does the brain deal with the enormous amount of information constantly coming through the senses?

Digital Data Compression

- Compression: the process of encoding information using less data than the original representation.
- Encoding = representing information in binary format (bits).

➢ Digital data compression: the process of removing some of the bits …

Why is digital data compression needed?



Data compression is needed for:

- Storage
- Transmission
- Search, Retrieval and Streaming
- Boosting computing and memory access speed

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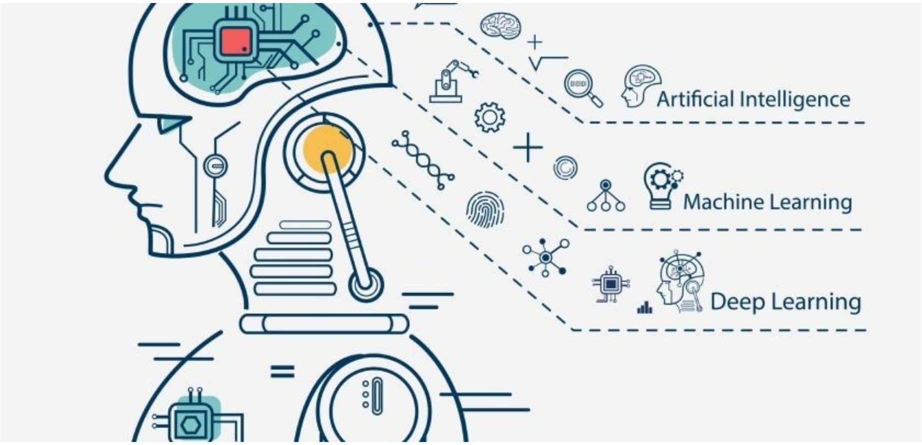
Data compression enables data-intensive applications:

- Artificial Intelligence

- Internet of things



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- Artificial Intelligence
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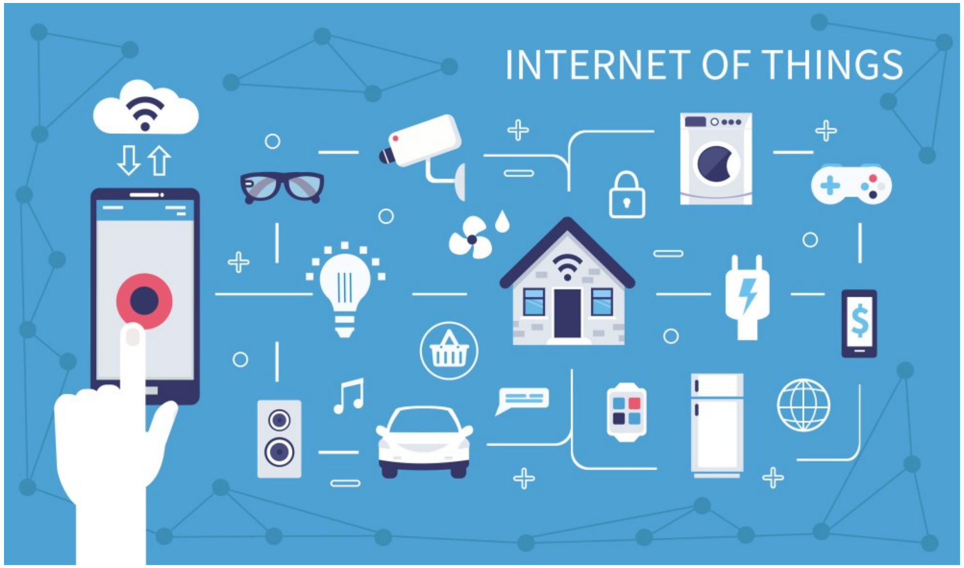

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Data compression contributes to:

- Cost, time and energy savings
- Green computing
- Lesser environmental impact

How does compression work?

Lossless Compression

Compress

Decompress returns data back to its original contents

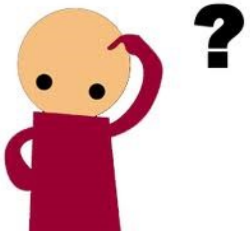
Lossy Compression

Compress

Decompress <u>does not</u> return data back to its original contents

	Lossless	Lossy
Image	RLE Huffman	Jpeg
Sound		Mp3
Video		Mpeg

Questions



- What is the difference between information and data?
- What is redundancy?

Information and Data

- Information carries meaning, it is useful, it contributes to knowledge.

- Data are representations of information, e.g. symbols, characters, bits …

➢ Compression strives to reduce data while preserving information

Redundancy

- Information that is expressed (represented) more than once

- Data that do not carry new information

- *Spatial redundancy*
- *Statistical redundancy*
- *Perceptual redundancy*
- *Temporal redundancy*

	Lossless	Lossy
Image	**RLE (spatial)** Huffman	Jpeg
Sound		Mp3
Video		Mpeg

Spatial redundancy

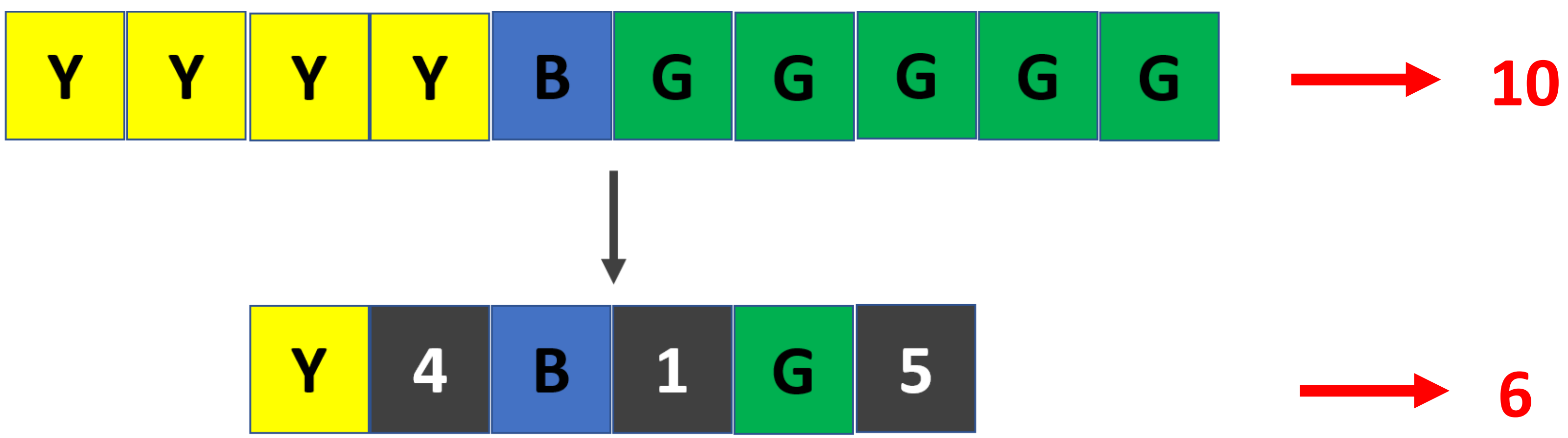
Ex 1: compressing images with RLE (lossless)

- RLE = Run Length Encoding
- Exploits spatial redundancy in images

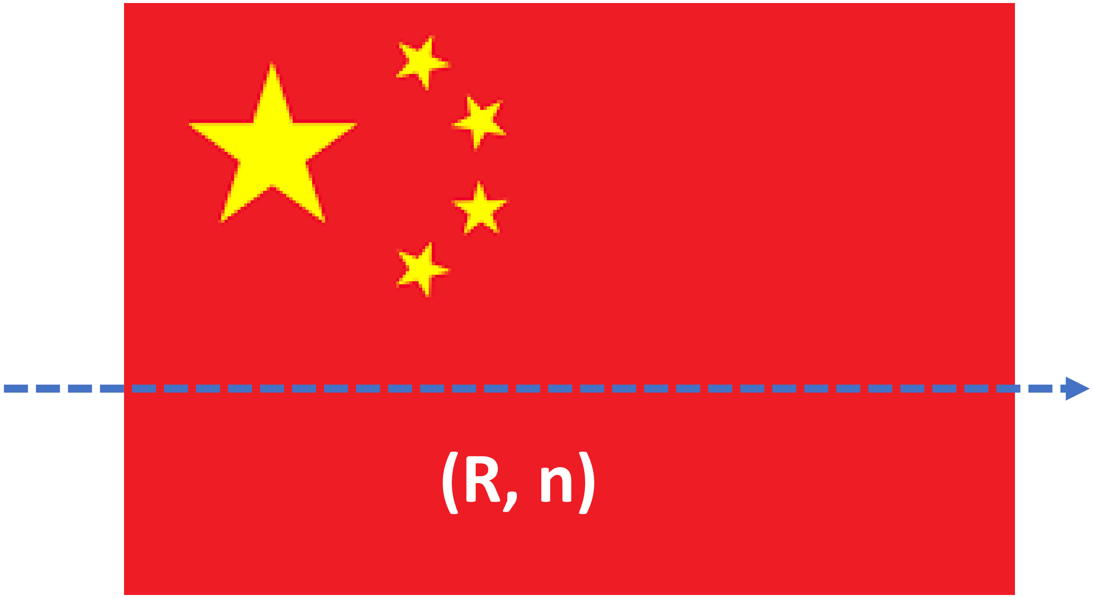
- Reduces any type of repeating sequence (run), once the sequence reaches a predefined number of occurrences (length)

- Instead of storing each pixel as an individual value, stores number pairs *(c, n)*, where *c* indicates the pixel colour and *n* is how many consecutive pixels have that colour.

Ex 1: compressing images with RLE (lossless)



Ex 1: compressing images with RLE (lossless)



Question

Which of the following statements about spatial redundancy is true?

An image has spatial redundancy when …

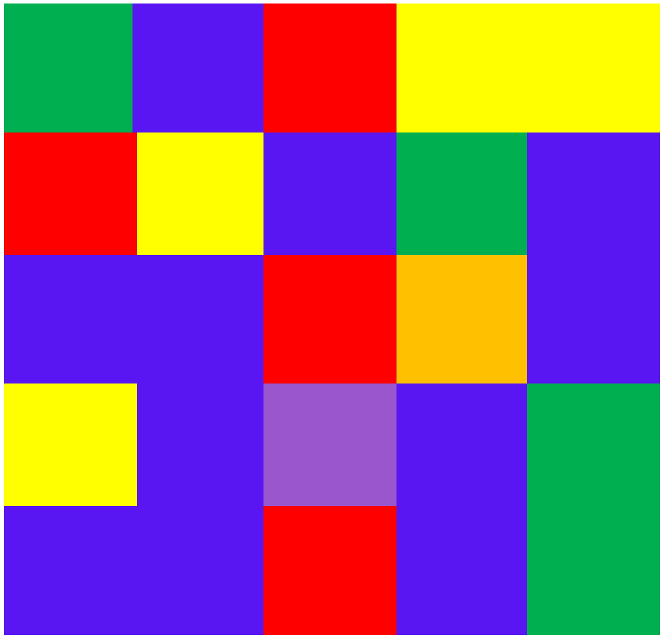
A. it contains a small number of colours

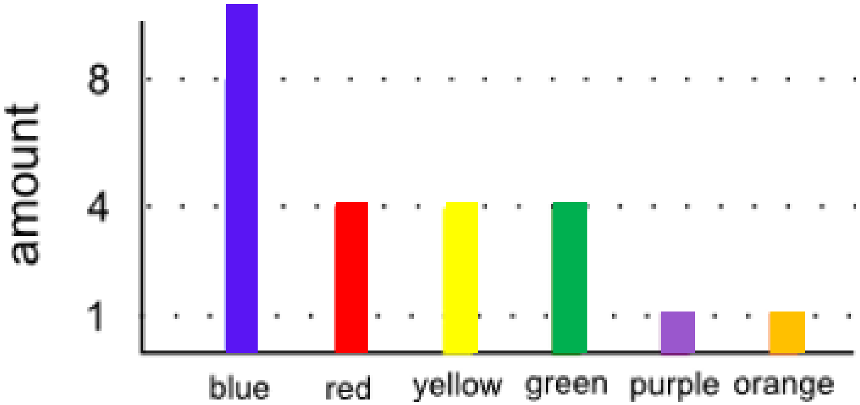
B. the colours are almost identical from one pixel to the next

C. it contains large areas of uniform colour

	Lossless	**Lossy**
Image	RLE (spatial) **Huffman (statistical)**	Jpeg
Sound		Mp3
Video		Mpeg

Statistical redundancy

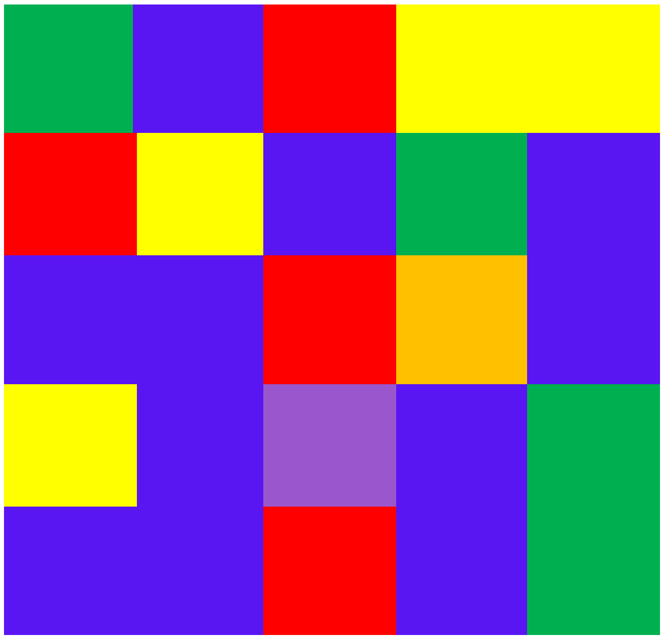




Ex 2: compressing images with Huffman (lossless)

- Exploits statistical redundancy in images
- Is an example of entropy compression
- Encodes frequent colours with short codes and infrequent colours with longer codes
- Fixed-length inputs become variable-length outputs
- Effective when probabilities vary widely

Ex 2: compressing images with Huffman (lossless)



Colour	freq.	bit code
	11	1
	4	011
	4	010
	4	001
	1	0001
	1	0000

25 pixels x 3 bits = **75 bits**

Huffman (variable length) encoding:

(11x1)+(4x3)+(4X3)+(4x3)+4+4 = 55 bits

Question

In which case will Huffman be the most efficient for image compression?

A. When the colours' probabilities are all the same
B. When the colours' probabilities vary widely
C. When there is many different colours

	Lossless	Lossy
Image	RLE (spatial) Huffman (statistical)	**Jpeg (perceptual)**
Sound		Mp3
Video		Mpeg

Perceptual redundancy

original

Compression: 10:1

Ex 3: compressing images with jpeg (lossy)

- Jpeg exploits perceptual redundancy
- Is an example of transform encoding

- Pixel data is converted to frequency coefficients

- Compression is done by removing the high frequency values

Transform encoding

- The idea is that changing the representation (domain) of data can sometimes make it possible to extract details that won’t be missed because they are beyond the acuity of human perception.

- High frequency components in images correspond to quick fluctuations of colour in a short space—changes that aren’t easy for the human eye to see.

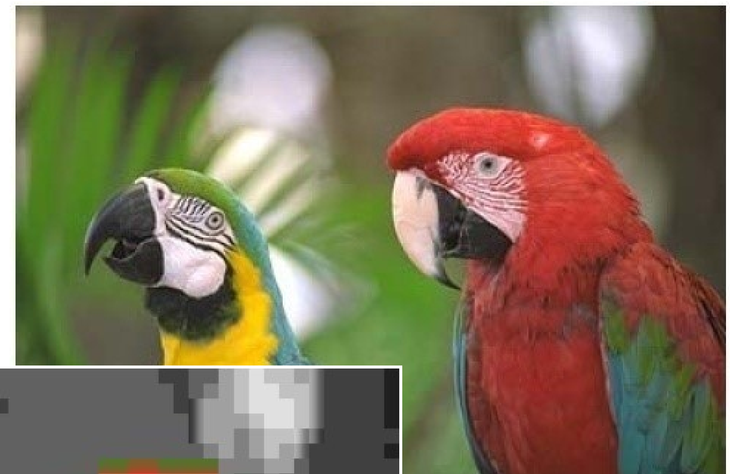
- Once the high frequency components of an image have been separated out, they can be removed.

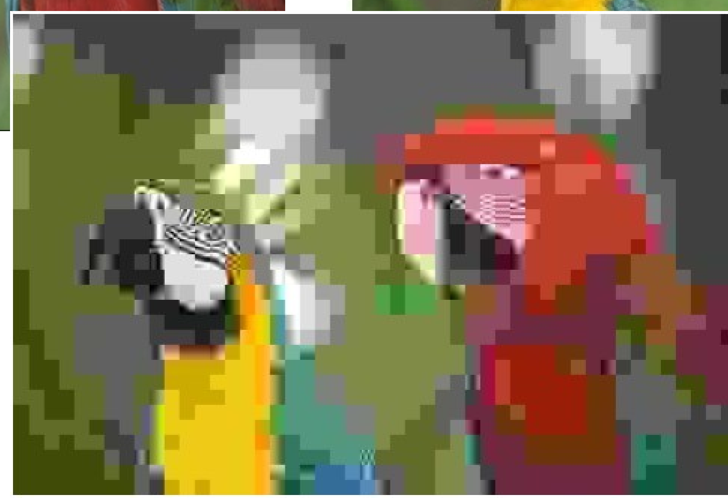
- Jpeg uses the ***discrete cosine transform*** (***DCT)***.

Ex 3: compressing images with jpeg (lossy)

original

Compression: 10:1





Compression: 100:1

	Lossless	Lossy
Image	RLE (spatial) Huffman (statistical)	Jpeg (perceptual)
Sound		**Mp3 (perceptual)**
Video		Mpeg

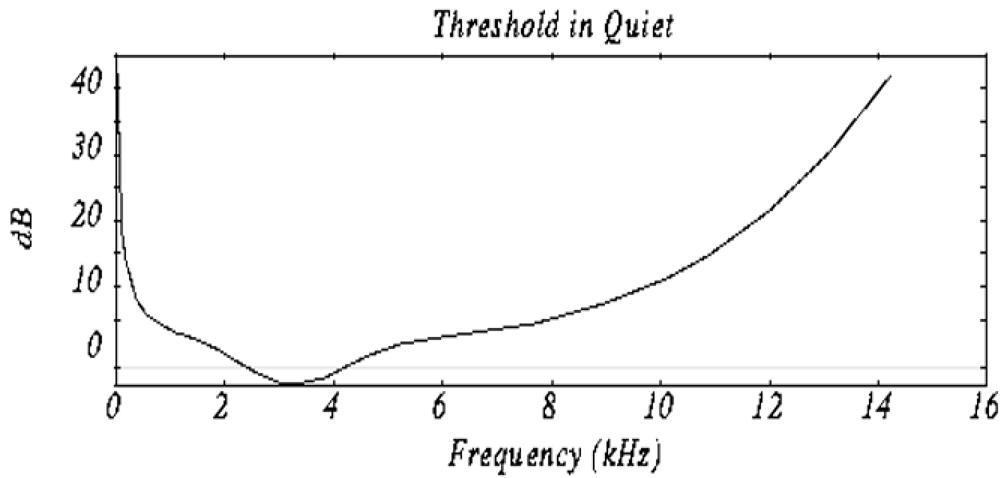
Ex 4: compressing music with mp3 (lossy)

- mp3 also exploits perceptual redundancy
- Uses knowledge from psychoacoustics to find inaudible data
- Psychoacoustics is the study of how the human ears and brain perceive sound
- Compression is done by removing the sounds that are either below the "*threshold of hearing*" or that are "*masked*" by other sounds.

Threshold of hearing

- Human's sensitivity to sound varies with frequencies: humans hear best in the range of about 1 to 5 kHz, which is close to the range of the human voice.

  - Threshold of hearing = minimal sound level at which sound can be heard



	Lossless	Lossy
Image	RLE (spatial) Huffman (statistical)	Jpeg (perceptual)
Sound		Mp3 (perceptual)
Video		**Mpeg (temporal)**

Temporal redundancy

Frame 1

Frame 2

difference frame

Ex 5: compressing video with mpeg (lossy)

- Mpeg exploits temporal redundancy

- It looks for similarities between consecutive frames

- Only the changes from one frame to the next are encoded

Question

In what kind of video content is temporal redundancy more likely to be found?

Conclusion

- What is data compression?

-> the process of encoding information using less data

- Why is it important?

-> for storage, transmission, etc.

- How can it be done?

-> by removing redundancy

- Examples of information compression techniques

-> RLE, Huffman, jpeg, mp3, mpeg

Other Considerations …

- How is digital data created in the first place?
- How can data be used to generate new information (without leading to data explosion)?
- Data, information, communicative intention, message
- What are the drawbacks of data compression?
- Data size and quality trade-offs
- Data applications, uses and users

Problem

Q7: Will you need to compress your images?

Q8: What kinds of techniques will be most suitable?